THE DEMAND FOR OIL AND ENERGY IN DEVELOPING COUNTRIES

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY

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R-2488-DOE
MAY 1980

			Form Approved OMB No. 0704-0188

Report Documentation Page

1. REPORT DATE **MAY 1980**	2. REPORT TYPE	3. DATES COVERED **00-00-1980 to 00-00-1980**
4. TITLE AND SUBTITLE **The Demand for Oil and Energy in Developing Countries**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Rand Corporation,1776 Main Street,PO Box 2138,Santa Monica,CA,90407-2138**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**64**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

PREFACE

The research reported here is part of Rand's work for the Department of Energy on energy utilization in the non-OPEC less-developed countries (NOLDCs). It presents an analysis of the relationship between energy demand in NOLDCs, on the one hand, and their economic growth rates and energy prices, on the other. A second study, analyzing household energy consumption by income class, and by urban and rural location of income recipients, is reported separately in Rand Report R-2515-DOE, *Household Energy Use in Non-OPEC Developing Countries*, by Judith C. Fernandez (May 1980).

The work described in the present report develops and applies several relatively simple and inexpensive methods for sizing future oil and energy demand in the NOLDCs in relation to their economic development and to world demand. Policy implications are sought in several overlapping areas: international energy markets, "North-South" energy relations, and U.S. economic and technical assistance to developing countries.

Briefings on an earlier version of this report were presented to the Department of Energy and other government agencies in July 1979. Comments and suggestions made at those briefings are reflected in this final version.

SUMMARY

How much of the world's oil and energy supply will the non-OPEC less-developed countries (NOLDCs) demand in the next decade? Will their requirements be small and thus fairly insignificant compared with world demand, or large and relatively important? How will world demand be affected by the economic growth of the NOLDCs?

SCOPE OF THE REPORT

In this report, we try to develop some reasonable forecasts of NOLDC energy demands in the next 10 years. Our focus is mainly on the demand for oil, but we also give some attention to the total commercial energy requirements of these countries. We have tried to be explicit about the uncertainties associated with our forecasts, and with the income and price elasticities on which they are based. Finally, we consider the forecasts in terms of their implications for U.S. policies concerning the NOLDCs and suggest areas of future research on NOLDC energy issues.

FORECASTING NOLDC ENERGY DEMAND

In 1976, total commercial energy consumption (including oil, gas, coal, and primary electricity) by all NOLDCs amounted to 9.3 million barrels per day (MB/D) in oil equivalent, or about 11.5 percent of global consumption, excluding the centrally planned economies. Oil consumption (excluding petrochemical feedstocks) by all NOLDCs in 1976 was 5.6 MB/D, or about 14 percent of the global figure. Oil imports by NOLDCs in 1976 were about 15 percent of world imports.

Our forecasts of NOLDC demand for the next decade cover an extremely wide range. For example, in our forecast of NOLDC oil demand in 1990, there is more than a threefold difference between our minimum of 5.73 MB/D and our maximum of 17.45 MB/D. As a share of world oil demand, these figures correspond, respectively, to a minimum between 7.8 percent and 10.6 percent, and a maximum between 23.5 percent and 32.2 percent.[1] The circumstances under which the extremes of our forecasted range would occur are, admittedly, quite unlikely, The NOLDC portion of the forecasted world oil imports in 1990 may be as small as 8.3 percent, or as large as 34.6 percent, assuming that the 1976 relationship between oil imports and oil consumption still prevails in 1990.

The wide range of these 1990 forecasts depends in part on the several different scenarios that we have assumed for NOLDC growth in real income (3 percent, 5 percent, or 7 percent per year) and for oil prices (increasing at 3 percent, or 5 percent per year in real terms). The range of the estimates narrows somewhat if

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[1]The range of the minimum and maximum percentage shares depends on whether we use the high (74 MB/D) or low (54 MB/D) estimates of world oil consumption in 1990 that have been made in other studies.

we confine our attention to a single scenario, one that perhaps may be considered the most reasonable and likely: an NOLDC income growth of 5 percent per year for the decade of the 1980s, and oil price increases at the same rate. In this case, our forecast of NOLDC demand in 1990 lies between 6.1 MB/D and 16.0 MB/D, or between 8.2 percent and 21.6 percent of forecasted world oil demand, respectively.

In any event, our forecasts still span an extremely broad range, reflecting a greater degree of uncertainty than that of previous studies by the World Bank, Organization for Economic Cooperation and Development (OECD), and other institutions. Our analyses include a comparison and an explanation of these differences.

The models on which our forecasts are based express current demand as a function of current income and price, measured in constant units, and of demand in the immediately preceding period. Data used in fitting the models cover 77 NOLDCs, which accounted, in 1976, for 79 percent of total oil consumption by all 124 NOLDCs.

The income and price elasticities with which our demand forecasts are associated also vary widely. The apparently simple question, "What is the income (or price) elasticity of demand for oil or energy in the NOLDCs?" admits of neither a simple nor singular answer. Using regression equations we have calculated four different types of elasticity, which vary by a factor of five or more across the four types. In general, our income elasticities are appreciably lower than those calculated in previous studies, but our price elasticities are similar to previous estimates.

There are three principal explanations for this wide range and for the uncertainties it reflects: (1) the variations in the scenarios assumed for NOLDC economic growth and for world oil prices, mentioned above; (2) variations in model specifications; and (3) variations in definitions and measurement of the price and income variables employed in the models. Among the three sources of uncertainty, the effects of differences in scenario assumptions and in the definition and measurement of variables are about equally great, whereas differences in model specification have the least effect. The scale and explanation of these uncertanties, as well as those associated with the more familiar standard errors of the estimating equations, are discussed in the text.

POLICY IMPLICATIONS

What policy implications follow from our forecasts?
The most obvious implication is that policy plans and pronouncements should take into consideration the inevitable large uncertainty inherent in forecasts of NOLDC oil and energy demand 10 years into the future. From the standpoint of U.S. energy policy, it may be prudent to focus on high NOLDC income growth rates, high income elasticities of demand, and low price elasticities, because they would seriously affect our oil supply. If supplies are tight because of high OECD demand or restrictive OPEC policies, increased NOLDC demand will further tighten the supply and push prices upward, assuming, of course, that other influences on world oil markets remain unchanged. Also, the durability of the OPEC cartel will tend to be strengthened, to the extent that its cohesion is helped by increased world demand. These results will only materialize if the NOLDCs experience rapid economic growth, if prices in world oil markets are high, and if income elasticities of demand

in the NOLDCs exceed their price elasticities. If NOLDC economic growth is slow, income elasticities are low, and price elasticities are high, pressure on world oil supplies and prices will be eased, and the cartel's cohesion will probably be strained, especially if OECD demand growth is also moderate or low. However, the political effects of slower NOLDC growth would be contrary to the interests of both the NOLDCs and the U.S.

U.S. policy therefore faces a dilemma. Accelerated growth and economic development in the NOLDCs—a general aim of U.S. *foreign* policy—is likely to mean a higher demand for oil and hence further pressure on world oil prices and supplies—consequences that U.S. *energy* policy would prefer to avoid. Attempts to resolve the dilemma—e.g., by encouraging the development of "soft"-energy technology, or nuclear technology, in the less-developed countries (LDCs)—are likely to be viewed by the NOLDCs as disingenuous and self-serving.

Thus, there is a real conflict, often unrecognized, between the international energy policy aims of the U.S. and the aims of its foreign policy in the arena of "North-South" relations.

However, the relationship between the international energy policy of NOLDCs and that of the U.S. may also be viewed from a different, and more congenial, standpoint. Instead of looking at the effect of NOLDC economic growth and oil demand on world markets, one may consider the effect of oil markets on the NOLDCs. From this standpoint, the interests of the U.S. and those of the NOLDCs are highly compatible. The NOLDCs and the U.S., as well as other developed countries, share strong interests in increased world oil supplies and lower, or constant, world oil prices. The developed countries and the oil-importing LDCs are on the *same* side of this "North-South" issue, not opposite sides, a point which is often missed or obscured in the conventional view of North-South issues.

By 1990, the oil import bill of the NOLDCs will be roughly between $47 billion and $88 billion (in 1979 dollars), over the central range of our forecasts for NOLDC oil demand in 1990. Hence, the incremental costs to the NOLDCs of their annual oil imports will almost surely be considerably greater than the benefits they might plausibly receive from any of the measures of international economic reform they have tried to achieve: for example, the proposed stabilization fund for LDC commodity exports; or the debt-service reduction that might result from a rescheduling of LDC international indebtedness; or the increases in foreign economic assistance sought by the NOLDCs and the U.N. Conferences on Trade and Development.

To alleviate the impediment to NOLDC economic growth that a large and growing burden of oil import costs would create, we suggest that it might be possible to obtain a concessional oil price from OPEC on petroleum sales to the NOLDCs. In spite of the numerous and serious obstacles and drawbacks to such a proposal, we suggest that it should be given further consideration. The attractiveness of two-tier pricing is twofold: (1) It may be a means of securing supplementary assistance for the NOLDCs from the OPEC countries. (2) It may provide a concrete way for the U.S., individually and together with other countries of the "North," to collaborate with the "NOLDC South" in furthering NOLDC interests.

Several research suggestions have evolved from our analysis of NOLDC energy demand.

1. In forecasting energy demand, one frequently encounters a familiar methodological issue: What is the relative importance of refinements and sophistication

in model specifications? How much effort should be devoted to them, as against the more mundane concerns, such as the exogenous assumptions or scenarios that are adopted, the definition and measurement of variables, the quality and comparability of the data used to measure them, and the inclusion or exclusion of specific dummy variables? Our results bear on the answer to this question in only a limited way, but one that is nonetheless interesting and significant.

In terms of their relative quantitative effects on the minimum and maximum demand forecasts for 1990, the "mundane concerns" have a much greater impact than do additional model refinements and sophistication.

2. Although the pattern of NOLDC price and income elasticities for several separate country subgroups—i.e., new industrial countries, and upper-income, middle-income, and lower-income countries—seems to be similar to that of the all-country group, there are a few interesting differences. Consequently, we suggest that in future research more attention be focused on the income and price elasticities, and their associated demand forecasts, of these separate country subgroups.

Such further work would be particularly useful in the case of the oil-importing "new industrial countries" (NICs): Korea, Taiwan, Brazil, Argentina, Hong Kong, and Singapore. Among the NOLDCs, these are the countries that have successfully surmounted the problem of limited oil supplies and rising oil prices while dramatically advancing their own economic development. To what extent have these countries relied on market forces and price changes, or on direct controls and rationing, in allocating scarce energy supplies? To what extent, and through what means, have they shifted production toward less energy intensive output and technology? And to what extent have they been able to pass on to others their increased oil import costs by simply raising prices of their exports? An analysis of the NICs' policies and patterns of energy use and adjustment should be particularly instructive and useful for the other NOLDCs.

3. Our study of energy and oil demand, like other similar studies, has looked at only one side of the relationship between economic development and energy use: the effect of economic growth, and of increases in oil energy prices, on demand. Econometric research should also focus on the reverse relationship: the effect of changes in energy use and energy prices on economic growth. Such research should consider the relationship between increases in real oil prices, as an independent variable, and economic growth in the NOLDCs (as a group and for various country subgroups, especially the NICs), as the dependent variable. The aim should be to provide an answer to this question: Do increases in international oil prices of X percent "cause" (or contribute to) a decrease in economic growth of Y percent in the importing countries, after proper allowance is made for the effects of other variables?

4. Finally, there are a number of research issues connected with the two-tier oil price proposal mentioned above. One issue that needs to be investigated is the extent to which the oil prices actually paid by some NOLDCs in recent years may have been *below* quoted world prices, e.g., because of rebates or concessional devices of various kinds. This investigation should cover information sources (including intelligence sources) beyond those used in the present study.

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Chapter 1

INTRODUCTION

How much of the world's oil and energy supply will the non-OPEC less-developed countries (NOLDCs) demand in the next decade? Will their requirements be small and thus fairly insignificant compared with world demand, or large and relatively important? How will world demand be affected by the economic growth of the NOLDCs?

Rand work on these questions began in the summer of 1978, after some preliminary work on energy issues in developing countries. In this study, we wanted to develop some reasonable forecasts of the range of NOLDC energy demands in the next 10 years. We also wanted to be explicit about the uncertainty associated with these forecasts, and with the income and price elasticities on which they are based. Finally, we wanted to consider their implications for U.S. policies concerning NOLDCs, and for future research on energy issues relating to these countries.

At the outset, we intended to devote equal attention to NOLDC demand for all energy sources and, separately, for oil. Subsequently, we decided to concentrate on oil demand for two reasons, one concerned with policy and the other with computational convenience: (1) The principal issues of energy policy that affect, and are affected by, the NOLDCs probably relate to the world market for oil rather than other fuels. (2) Information on user prices for other commercial energy sources (gas, coal, hydropower) is more difficult to collect and even less reliable than information on oil prices.[1]

For these reasons, concentrating on oil, rather than on all energy sources, seemed appropriate within the limits imposed by our time and budget constraints. Although some results will be reported for total commercial demand for energy, and its associated income and price elasticities, our main emphasis is on NOLDC demand for oil. While we do not attempt to estimate cross elasticities of demand between oil and other fuels, the range of uncertainty in our reported estimates for oil demand is probably sufficient to cover a reasonable allowance for cross elasticities.[2]

The remainder of the report is organized as follows: Chapter 2 provides a brief background, summarizing previous estimates (or assumptions) about price and

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[1] A valuable recent study by the World Bank collected separate price data for solid fuels, gas, and primary electricity, as well as oil, for a sample of thirty-five countries, compared with the seventy-eight in our data set. See B. J. Choe, *Energy Demand Prospects in Non-OPEC Developing Countries,* The World Bank, June 1978.

[2] If it is assumed that oil prices are likely to rise relative to prices of other fuels, some substitution of these fuels in place of oil should be expected in the future. On the other hand, income cross elasticities may lead in the opposite direction: they may promote the substitution of oil in place of other fuels as income rises, thereby offsetting the price effect. Some preliminary work by Judith Fernandez, dealing with the proportion of various fuels in total energy used by households at different income levels, suggests that the income cross elasticity of demand for oil in developing countries may be lower than is usually assumed. (See Judith C. Fernandez, *Household Energy Use in Non-OPEC Developing Countries,* The Rand Corporation, R-2515-DOE, May 1980. However, we do not attempt to estimate the relative size of the two cross elasticities.

income elasticities of demand, previous demand forecasts, and the methods used in making them. Chapter 3 summarizes the models and data we have used, and our principal results: price and income elasticities for the NOLDCs as a group, and for several subgroups; forecasts of NOLDC oil and energy demand in 1985 and 1990; and the scaling of these forecasts relative to world demand for both energy and oil. Finally, Chapter 4 suggests implications for U.S. policy and for further research.

Chapter 2

BACKGROUND: PREVIOUS ESTIMATES
AND METHODS

NOLDC OIL AND ENERGY CONSUMPTION

In 1976, commercial energy consumption (including oil, gas, coal and primary electricity) by all NOLDCs amounted to 9.3 million barrels per day (MB/D) in oil equivalent, or about 11.5 percent of global consumption, excluding the centrally planned economies. Oil consumption (excluding petrochemical feedstocks) by all NOLDCs in 1976 was 5.6 MB/D, or about 14 percent of the corresponding global figure. The NOLDCs account for a somewhat larger share of international oil imports because they import a larger share of their consumption than do the developed countries as a whole. In 1976, the NOLDCs accounted for 4.7 MB/D, or 15.3 percent of world imports. Oil accounted for 60 percent of all commercial energy consumed by the NOLDCs in 1976.[1] Distribution of these total figures among the upper-income, middle-income, and lower-income NOLDCs is shown in Table 1.

Table 1

ENERGY AND OIL CONSUMPTION AND IMPORTS, 1976: NON-OPEC
LESS-DEVELOPED COUNTRIES (NOLDCs)
(MB/D oil equivalent)

Consumer	Commercial Energy Consumption[a]	Oil Consumption[a]	Oil Imports[a]
1. World[b]	80.5	39.2	30.6
2. Non-OPEC LDCs	9.3 (11.5%)	5.6 (14.3%)	4.7 (15.3%)
3. Upper-income NOLDCs	4.8 (6.0%)	3.7 (9.4%)	2.9 (9.6%)
4. Middle-income NOLDCs	1.8 (2.2%)	1.2 (3.1%)	1.1 (3.6%)
5. Lower-income NOLDCs	2.7 (3.3%)	0.7 (1.8%)	0.7 (2.1%)

SOURCE: *World Energy Supplies*, U.N. Series J, 1978. A list of the countries in each income category is given in Table 5.

[a]Shares of corresponding world total consumption or imports are shown in parentheses. See the section on energy consumption in Chapter 3 for definitions of oil consumption and commercial energy consumption.

[b]Excluding the centrally planned economies.

Among the NOLDCs, energy and oil consumption are highly concentrated. In 1976, six countries (India, Brazil, Mexico, Argentina, Korea, and Taiwan) accounted

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[1]Figures cited are from *World Energy Supplies*, U.N. Series J, 1978.

for 60 percent of commercial energy consumption and 46 percent of the oil consumption for all NOLDCs (i.e., 124 countries) for which data are available.

PREVIOUS FORECASTS

Several forecasts, summarized in Table 2, have previously been made of future NOLDC energy consumption. Forecasts of world consumption of oil and commercial energy, reflected in the Table 2 figures for the OECD, WAES, and Eden studies, are shown in Table 3. The income and price elasticities, on which the NOLDC forecasts in Table 2 are based, are summarized in Table 4.

What can be concluded from these forecasts?

First, estimates of *NOLDC energy consumption* for 1985 range between 13.3 MB/D and 22.8 MB/D, and between 11.8 percent and 20.5 percent of global consumption, compared with 11.5 percent in 1976. The median is 16.8 MB/D. For 1990, the estimates range between 16.9 MB/D and 27.0 MB/D, and between 12.1 percent and 21.0 percent of global consumption.

Second, forecasts of *NOLDC oil consumption* in 1985 range between 6.2 MB/D and 11.4 MB/D, and between 10.9 percent and 21.4 percent of global consumption, compared with 14.3 percent in 1976. For 1990, the corresponding figures are 10 MB/D and 13.5 MB/D, and between 15.8 percent and 24.5 percent of global consumption.

Third, previous estimates of *NOLDC income elasticities* of demand for *energy* vary from .40 in the short run to 1.94 in the long run. Estimates of energy *price elasticities* range from $-.09$ in the short run to $-.38$ in the long run. For *oil*, the NOLDC *income elasticities* vary between .40 in the short run and 1.86 in the long run. *Price elasticities* for oil range from $-.05$ in the short run to $-.50$ in the long run.

COMPARISON BETWEEN PREVIOUS METHODS AND THOSE
USED IN THIS STUDY

Among the studies referred to in Tables 2, 3, and 4, above, only two (by Lambertini and Choe) used econometric models to estimate price and income elasticities as a basis for their forecasts. The other studies either assumed a price elasticity or ignored it entirely, basing their forecasts on an assumed income elasticity, usually derived from the historical relation between growth of income and growth of energy consumption. This income elasticity was then used to derive oil- or energy-demand estimates by assuming a particular economic growth rate for the developing countries.

Lambertini and Choe use a lagged adjustment model, which expresses current demand as a function of (a) current income and price and (b) demand in the immediately preceding period.[2] We use a similar model in deriving the estimates reported

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[2]See A. Lambertini, *Energy and Petroleum in Non-OPEC Developing Countries*, Annex II, World Bank Staff Working Paper No. 229, Washington, D.C., 1976. A similar model has been used to estimate energy demand in developed countries. See W. D. Nordhaus, *International Studies of the Demand for Energy*, North Holland, 1977. For a further explanation and derivation of the model, see Chapter 3 and Appendix A.

Table 2

FORECASTS OF ENERGY CONSUMPTION FOR NOLDCs: 1980, 1985, 1990

(MB/D oil equivalent)

Source of Forecast	1980	1985	1990
Commercial Energy Consumption			
OECD[a]	11.3 (11.9%)	15.0 (12.8%)	—
WAES[b]	11.6-12.6 (10.7-11.6%)	14.6-17.8 (11.8-14.4%)	18.0-22.5 (12.1-15.2%)
Energy Research Group (Eden)[c]	20.0 (19.8%)	22.8 (20.5%)	27.0 (21.0%)
World Bank (Lambertini)[d]	11.2-11.4	13.3	16.9
World Bank (Choe)[e]	12.2	16.8-17.4	18.9-24.9
Oil Consumption			
OECD	5.3 (10.8%)	6.2 (10.9%)	—
WAES	7.5-8.3 (13.9-15.2%)	9.5-10.7 (15.0-16.9%)	11.7-13.5 (15.8-18.2%)
Energy Research Group (Eden)	9.0 (19.0%)	11.4 (21.4%)	13.3 (24.5%)
World Bank (Lambertini)	6.2-6.8	7.8	10.0

NOTE: Figures in parentheses show the corresponding shares of world consumption of commercial energy and oil, respectively, based on forecasts presented in each of the studies referred to below. See Table 3 for the detailed world forecasts.

[a] Organization for Economic Cooperation and Development, *World Energy Outlook*, Paris, 1977.

[b] Workshop on Alternative Energy Scenarios, *Energy: Global Prospects, 1985-2000*, The M.I.T. Press, Cambridge, Mass., 1977. The range of the WAES forecasts results from varying assumptions about changes in prices and income. Oil consumption forecasts for 1990 have been derived by applying the WAES income elasticity for commercial energy consumption to the WAES estimate of oil consumption in 1985.

[c] Energy Research Group (Cambridge), R. Eden et al., *Report on Energy Demand, 1975-2000*, 1977.

[d] World Bank, A. Lambertini, *Energy and Petroleum in Non-OPEC Developing Countries, 1974-1980*, World Bank Staff Working Paper No. 229, Washington, D.C., 1976. Lambertini's forecasts for 1980 were extended to 1985 and 1990 by Gordian Associates, *Requirements for Financing Energy Development in Non-OPEC Less-Developed Countries through 1990*, 1976.

[e] World Bank, B. J. Choe, *Energy Demand Prospects in Non-OPEC Developing Countries*, 1978. The Choe estimates are based on a panel of 35 developing countries. He extends these estimates to the NOLDCs as a whole by assuming a constant ratio between energy demand in all NOLDCs and his country panel. In 1975 that ratio was 1.23 [=(9.67 MB/D)/(7.87 MB/D)]. Choe's original estimates reached to 1985. We have projected them to 1990 by using his price and income elasticities (for upper-middle-income and lower-income NOLDCs), and the two differing price and income scenarios that he postulates. One scenario assumes a price increase of 15 percent and a gross-domestic-product (GDP) growth of about 30 percent over the 1980-1985 period. The second scenario assumes no price increase, but the GDP growth rate is maintained. Choe does not make separate forecasts for oil.

Table 3

FORECASTS OF WORLD[a] OIL AND COMMERCIAL ENERGY CONSUMPTION
(MB/D)

Source of Forecast	1980	1985	1990
Oil Consumption			
OECD[b]	49.22	56.44	--
WAES[c]	54.00	63.00	74
Energy Research Group (Eden)[d]	46.56	53.05	54
Commercial Energy Consumption			
OECD[b]	95.34	116.84	--
WAES[c]	108.60	123.20	148
Energy Research Group (Eden)[d]	101.00	111.00	128

[a]Excluding communist countries.

[b]Organization for Economic Cooperation and Development, *World Energy Outlook*, Paris, 1977. World forecasts consist of forecasts for OECD countries plus NOLDCs. The forecasts are based on a reference scenario case that assumes a growth rate of 4.3 percent in gross domestic product (GDP) until 1980 and a 4.1-percent GDP growth rate from 1981 to 1985, for the OECD countries; 5.6-percent GDP growth rate to 1980 and a 6.1-percent GDP growth rate from 1981 to 1985, for the NOLDCs. In addition, OECD assumed constant oil prices in real terms at $11.51 per barrel for Arabian light crude to 1985.

[c]Workshop on Alternative Energy Scenarios, *Energy: Global Prospects, 1985-2000*, The M.I.T. Press, Cambridge, Mass., 1977. Based on scenario C to year 1985: 5.2-percent GDP growth rate and constant 1975 oil price at $11.50; and on scenario C-2 from 1985 to 2000: 4-percent GDP growth rate and energy price rising to $17.25 by the year 2000.

[d]R. Eden et al., *World Energy Resources, 1985-2000*, World Energy Conference, 1978. Based on scenario L-4 (low growth) with a 3.1-percent GDP growth rate and an energy price elasticity of response of -0.3.

here, but there are several important differences between our work and the prior studies:

1. Variations of the model specification are used, for reasons discussed in Chapter 3, to test the robustness of the estimates.
2. Explicit allowance is made for the separate effects of time trends and country-specific characteristics associated with the historical data.
3. Estimates are made of the uncertainty associated with the forecasts and elasticities.
4. Some of the variables in the model are defined and measured in alternative ways (e.g., gross domestic product is deflated and converted to dollars by differing methods) so that comparisons can be made.

Table 4

INCOME AND PRICE ELASTICITIES OF DEMAND FOR ENERGY AND OIL IN NOLDCs

Source of Forecast[a]	Income Elasticities		Price Elasticities	
	Short Run	Long Run	Short Run	Long Run
All Commercial Energy				
OECD	.95	.96	--	--
WAES	1.19	1.04 to 1.10	--	--
Energy Research Group (Eden)	--	.73 to .80	--	-.3
World Bank (Lambertini)	--	--	--	--
World Bank (Choe)	.40 to .68	1.15 to 1.94	-.09 to -.15	-.28 to -.38
Oil				
OECD	--	.32	--	--
WAES	1.19	1.04 to 1.10	--	-.42
Energy Research Group	--	--	--	--
World Bank (Lambertini)	.40 to .56	1.17 to 1.86	-.05 to -.11	-.13 to -.50

[a]See Table 2. The range of elasticities in the World Bank studies (by Lambertini and Choe) represent differing estimates for high-, middle-, and low-income less-developed countries. The WAES study presents income elasticities but does not show a price elasticity. However, we have derived the long-run price elasticity that is embedded in the study by attributing to price effects the difference between the consumption forecasts reported in the WAES study and the forecasts that would result from the cited income elasticities operating alone.

5. A substantially larger number of developing countries are covered in the data. (Our data set covers 77 NOLDCs, compared with the 29 used by Lambertini and 35 by Choe.)

6. We explore the implications of these estimates for policy, as well as for research.

Chapter 3

ANALYSIS AND ESTIMATION

METHODS AND MODELS

Our aim is to estimate price and income elasticities of demand for both energy and oil, and to use these estimates to forecast NOLDC demand over the next decade.

Although we want to estimate demand, the data on energy and oil consumption that we use in estimating the parameters represent intersections between demand and supply schedules. Identification of a separate demand function is hindered by the confounding of demand and supply influences that is inherent in observations of actual consumption.

To avoid this identification problem, we make a strong assumption. During the 1967-1976 period, we assume that the NOLDC demand function (schedule) was (relatively) stable, whereas the cartelized supply adjusted (shifted) along the stable demand schedule. In effect, we assume that prices were set independently of NOLDC demand. OPEC's increasingly effective coordination of the producers' supply and pricing policies during this period makes this assumption plausible. Successive observations of actual NOLDC *consumption* can now be construed as delineating the NOLDC *demand* schedule, as suggested in Fig. 1.
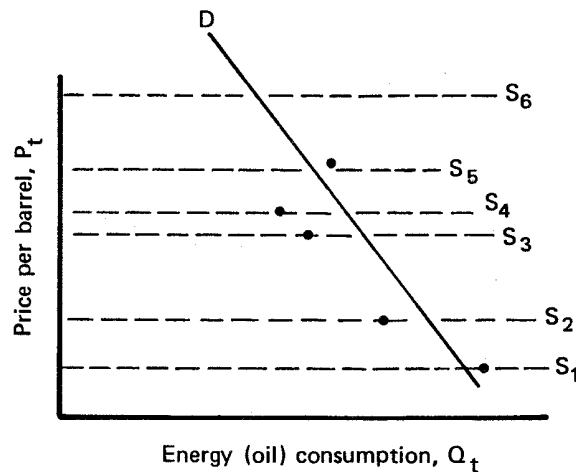
Fig. 1—Hypothetical adjustment of supply
to stable demand function

The points shown in Fig. 1 represent hypothetically observed energy or oil consumption by the NOLDCs in successive years, t. We assume that they identify a stable demand function, D, and are randomly distributed around it, whereas the shifting OPEC price decisions are indicated by the dotted S curves.

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Two behavioral relationships define the principal demand model that we use:
(1) The level of desired or potential energy demand depends on the price of energy
(oil), and on the level of economic activity (income). In accordance with standard
theory, the desired level of demand will be greater when prices are lower, and
income is higher, and conversely. (2) A period of adjustment is required (i.e., a
period in which suitable plans and operating decisions by industrial and household
consumers can be made) before actual demand can be brought to the desired level.
Consequently, the response of energy (oil) demand to changes in prices and income
will be more limited in the short run than in the longer run.

By combining these two relationships, we obtain the first model:[1]

$$Q_{i,t} = a_0 \left(Y_{i,t}^{\alpha} P_{i,t}^{\beta} \right)^{1-\lambda} Q_{i,t-1}^{\lambda} , \qquad (1)$$

where Q = energy (or oil) demand (in millions of barrels of oil)
 Y = gross domestic product (in constant units),
 P = energy prices (in constant units),
 i = 1,2, ... ,77 (non-OPEC less-developed countries),
 t = 1967, ... ,1976,
 λ = is a geometric adjustment lag, $(1 \geq \lambda \geq 0)$. (A low value for λ im-
     plies that actual demand adjusts rapidly to income and price changes
     and, hence, that desired demand is realized quickly; the converse is
     implied as λ approaches unity.)

The parameters α and β are, respectively, the long-run income and price elasticities
of demand, which take effect as adjustment is made to changes in income and
prices. The corresponding short-run elasticities, which persist until the adjustment
is realized, are $\alpha(1 - \lambda)$ and $\beta(1 - \lambda)$, respectively. The lag parameter, λ, and the
short-run elasticities are estimated from the econometric model by ordinary least
squares. By dividing the short-run elasticities by $(1 - \lambda)$, we obtain the long-run
income and price responses, α and β, respectively.

Model (1) is the most familiar and frequently used method for estimating the
response of energy demand to price and income changes.[2] Despite the frequency of
its use, however, the model presents a number of complications, both theoretical
and empirical. One empirical complication is due to the various options that exist
for measuring the variables of the model, either because of the latitude allowed by
the theory or because of the limitations of the data, or for both reasons. These
measurement options, and how they are managed in our statistical work, will be
discussed below.

A theoretical shortcoming of model (1) lies in the lag adjustment process that
it entails.[3] Specifically, the model assumes that the time lag, $(1 - \lambda)$, for energy
demand to adjust to its desired level will be exactly the same as that required for
changes in income and in price. Yet this seems counterfactual. For industrial users

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[1] Derivation of the model is summarized in Appendix A.

[2] See W. D. Nordhaus, *International Studies of the Demand for Energy*, North Holland, 1977; A.
Lambertini, *Energy and Petroleum in Non-OPEC Developing Countries*, the World Bank, 1976; and B.
J. Choe, *Energy Demand Prospects in Non-OPEC Developing Countries*, the World Bank, 1978.

[3] We are indebted to Michael Kennedy for emphasizing and clarifying this point.

especially, it would seem more reasonable to assume that it will take longer to adjust to changes in energy or oil prices than to adjust to changes in the level of economic activity (i.e., in income). Income changes will usually generate quick responses in energy demand because income changes imply concurrent changes in employment and capital utilization, which, in turn, determine energy demand. Price changes, by contrast, are likely to have a delayed effect on energy demand because the existing capital equipment of industrial users tends to "lock" them into a specific pattern of energy demand, if the levels of economic activity and capital utilization are held constant. Until the capital stock is altered—through depreciation, modification, and replacement—energy demand will probably be little affected by price changes independent of income changes.

To take account of this shortcoming, we modify model (1) so that the adjustment of actual demand to desired energy demand is assumed to take place almost immediately in the case of income changes, but the lag structure of the model is retained for price changes. Model (2a) is one way of interpreting this point.

In model (2a), the *ratio* between current energy demand and current income raised to the power a is expressed as a lagged function of price, and of a lagged relationship between energy consumption and income in the preceding period:

$$\frac{Q_{i,t}}{Y^{\alpha}_{i,t}} = a_0 \left(P^{\beta}_{i,t}\right)^{1-\lambda} \left(\frac{Q_{i,t-1}}{Y^{\alpha}_{i,t-1}}\right)^{\lambda}$$

or   (2a)

$$Q_{i,t} = a_0 \left(P^{\beta}_{i,t}\right)^{1-\lambda} Y^{\alpha}_{i,t} Q^{\lambda}_{i,t-1} Y^{-\alpha\lambda}_{i,t-1}$$

In our empirical work, we chose not to fit the second model as written, but to fit the more general model instead:

$$Q_{i,t} = a_0 \left(P^{\beta}_{i,t}\right)^{1-\lambda} Q^{\lambda}_{i,t-1} Y^{\alpha_1}_{i,t} Y^{\alpha_2}_{i,t-1}$$ (2)

This was done primarily for computational reasons. We want to estimate model parameters by ordinary least squares. However, although both models (1) and (2) are linear in the logarithms of the variables, the original (2a) version of model (2) imposes the following constraint:

$$a_2 = -a_1\lambda.$$

Estimating parameters with such a constraint requires cumbersome nonlinear least-squares computations, which we wish to avoid.

Four questions about these models deserve comment: (1) Should energy demand (Q) and economic activity levels (Y) be measured in per capita or aggregate terms? (2) How should particular variables be defined in light of alternative exchange rates and price deflators? (3) Should country-specific dummy variables be included in the models? (4) Should allowance be made for the independent effects of time trends associated with the historical data?

Per Capita and Aggregate Variables

One would expect per capita energy consumption or per capita oil consumption to be relatively more stable than aggregate consumption. But forecasts using per capita models require separate population projections and may therefore be less accurate for estimating total consumption.[4] We therefore retain both types of dependent variables, and report their predictions separately.

Defining and Measuring the Variables

A number of problems are presented by the data, such as those pertaining to availability, reliability, consistency among different sources, and comparability among countries. These problems will be addressed in the discussion under "The Data Set," below. The particular problem of defining and measuring exchange rate conversions should be noted here.

Income and price variables present familiar problems. We would like to employ an income measure that accurately reflects the real (i.e., price adjusted) level of economic activity across countries and over time. However, currency devaluations create large discontinuities when national products or prices are converted from local currencies to dollars—discontinuities that do not reflect changes in the real terms. We tried many alternative methods to deal with this problem, favoring two in particular:

1. Converting local currency to U.S. dollars by using the given year's local exchange rate and then using the U.S. consumer price index (CPI) to translate back to 1970 dollars.
2. Adjusting local currencies back to 1970 dollars by using local price deflators and alternative estimates of the appropriate exchange rate. Our preferred estimate of the latter is the 3-year average for 1969, 1970, and 1971. In fact, our estimates were insensitive to the alternatives tried.

Country-Specific Dummy Variables

We investigated the need for country-specific indexing parameters because the relationship between consumption and price and income, although less predictable

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[4]However, one of our reviewers, Michael Kennedy, advances the (arguable) proposition that population forecasts are likely to be more accurate than income forecasts, and hence per capita estimates might be preferable on this ground.

across countries, is more likely to be stable within countries from year to year. (Evidence of this stability can be obtained by examining residual plots from regressions that include only price and income; residuals for each country tend to be clumped and to be either all positive or all negative.)

There are two ways to index consumption levels. One is to enter energy or oil demand (consumption) in the previous time period as an independent variable, $(Q_{i,t-1})$. In that case, the stability of consumption within countries from year to year would imply that the coefficient on previous consumption would be close to unity. The malady with the residuals, noted above, would therefore be cured. However, such a coefficient implies n-year forecast variances roughly equal to n times a single year's variance. Hence, the width of prediction intervals grows quickly as the prediction period lengthens.

A second alternative is to enter country-specific dummy variables into the model's specification. This procedure adds many parameters to the model, each estimated with considerable uncertainty, and yields highly uncertain forecasts. So, neither alternative is without pitfalls.

Entering dummy variables for each country is tantamount to subtracting country-specific means from each variable. Essentially, one obtains the coefficients on price, income, and lagged consumption by performing an ordinary linear regression directly on these normalized series, which implies that the variables have been purged of cross-country explanatory information. (For example, the fact that Argentina is a larger consumer of oil than Egypt is discarded for the purposes of estimating price and income coefficients, and all that remains is the time variation of series within countries.) This procedure is reasonable if price and income are correlated with important omitted variables that are constant within countries, e.g., historical dependence on oil consumption. Such effects are controlled by the inclusion of dummy variables, and the resulting normalized regressions more accurately reflect what happens when all other variables are held constant.[5]

We include the results for the models with and without dummy variables because of their statistical significance and the contrasting predictions that result.

Time Trends

Preliminary analysis of the 1967-1976 data confirmed the existence of a time-related influence on energy consumption, independent of the price and income variables in the models. To allow for the separate effect of time, we have included a time variable in those models that use the country dummy variables. We have not included the time variable in the models without country dummies for several reasons. One is to facilitate comparison between our results and those of other studies that did not use either country dummies or time-trend variables.[6]

Also, preliminary data analysis in which the models were used without dummy

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[5]On the other hand, if price and income are *not* correlated with important omitted variables that remain constant within countries, then the inclusion of dummy variables has less merit. Moreover, country-specific influences that are uncorrelated with price and income are already captured by the lagged energy demand variable, Q_{t-1}, in the models. Consequently, there is a tension between including both the country-specific dummy variables and the lagged energy variables for each country. The dummies tend to drain the lagged variable, Q_{t-1}, of the country-specific effects it would otherwise reflect.

[6]See Lambertini, op. cit.

variables indicated that inclusion of the time variable either reversed the predicted signs of the price or income coefficients or generated statistically insignificant coefficients. Evidently, the effect of time in the models without dummy variables is more fully reflected in the lagged energy consumption variable, $Q_{i,t-1}$, than is the case in the models with dummy variables.

THE DATA SET

Here we will describe (a) the data that we used for our estimates and forecasts, (b) the final form of each of the variables used, and (c) the modifications that we made in the published data series. Finally, we will list the countries used in the sample.

Oil Price Data

Reliable data on energy prices are not readily available for each of the NOLDCs. Even data on oil prices paid by the NOLDCs are subject to question for many reasons. Spot prices differ from contract prices, and contract prices differ according to their time horizon. Some NOLDCs may receive rebates, or concessional financial aid from suppliers to offset a portion of price increases charged in international markets. Such special arrangements are typically not ascertainable from published sources. Furthermore, NOLDC governments may apply subsidies or taxes on oil, or on other energy sources, for their own policy reasons. Hence, the prices to which industrial and household users respond may differ from prices charged on international markets.

We have not found a satisfactory way of dealing with many of the data problems relating to the price variable in the models. Instead, we were obliged to make several simplifying assumptions and to adopt two alternative measures for this variable.

The first alternative adopted was the price of Saudi Arabian light crude, 34° f.o.b. Ras Tanura, as a general indicator of the international oil price (P_t) for the time period, $t = 1967, \ldots, 1976$. We converted the series to 1970 U.S. dollars by using the World Import Price Index (WIPI); this conversion resulted in the adjusted price, P'_t. The following data were used in this adjustment:

Year	Oil Price in Current U.S. Dollars (P_t)	WIPI[a]	Oil Price in Constant U.S. Dollars (P'_t)
1967	1.30	94	1.382
1968	1.30	97	1.340
1969	1.30	102	1.274
1970	1.30	100	1.300
1971	1.65	95	1.736
1972	1.90	99	1.919
1973	2.70	139	1.942
1974	9.76	199	4.904
1975	10.72	215	4.986
1976	11.51	217	5.304

[a] Data were derived from International Monetary Fund (IMF), *International Financial Statistics* (various issues, 1974–1978).

Deflation by the WIPI means that P'_t measures changes in oil prices relative to changes in prices of other imports. This deflation has the effect of damping somewhat the large increase in oil prices of 1973-1974 that would be manifest if, for example, the U.S. consumer price index had been used as the deflator.

A second price measure, $(P_{i,t})$, was also used to reflect the sometimes differing oil import price actually paid by each individual country. This measure consists of the ratio between the value and the quantity of oil and other energy imports.[7] The U.N. trade data show the cost, insurance, and freight (CIF) value of energy imports in current U.S. dollars, and the quantity of imports in barrels of oil equivalent.[8] Value and quantity data are only available for 23 of the 77 countries in our entire sample (see below).[9]

We converted $P_{i,t}$ to 1970 dollars by using the U.S. consumer price index $(CPI)_{us,t}$:

$$P''_{i,t} = P_{i,t}/CPI_{us,t} \, ,$$

where $P_{i,t}$ = oil import price for country, i, at time, t, in U.S. dollars, and $CPI_{us,t}$ = U.S. consumer price index.

Gross Domestic Product

As noted earlier, the theory implies that energy demand should respond to changes in the real level of economic activity. We therefore want a measure for this variable that will be reasonably comparable across countries and over time. Toward this end, gross domestic product, Y, is expressed in 1970 U.S. dollars for every sample country and time period from 1967 through 1976.

We estimated the variable Y in two ways: (1) We changed the gross domestic product (GDP) from current local currency prices into 1970 currency units via the local GDP price deflator, or consumer price index, and then converted them to 1970 U.S. dollars with the average 1969-1971 exchange rates:

$$Y_{i,t} = [GDP_{i,t}/DEF_{i,t}]/[(E_{i,69} + E_{i,70} + E_{i,71})/3].$$

(2) We converted the GDP to U.S. dollars by using each year's exchange rate, $E_{i,t}$, and then deflated them to 1970 U.S. dollars by using the U.S. consumer price index:

$$Y'_{i,t} = (GDP_{i,t}/E_{i,t})/CPI_{us,t},$$

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[7] As reported by the U.N. *International Trade Statistics Yearbook*, various issues 1975, 1976; hereinafter referred to as the U.N. *Statistical Yearbook*.

[8] The quantity of oil imports was converted from the original figures, which were expressed in metric tons of oil equivalent.

[9] For the countries without the "own-price" $(P_{i,t})$ data, we continued to use the Ras Tanura (P_t) figures.

where $GDP_{i,t}$ = GDP in local currency for country, i, at time, t.[10]

$\quad\quad E_{i,t}$ = local currency/dollar exchange rate,

$\quad\quad DEF_{i,t}$ = GDP price deflator when available, otherwise $CPI_{i,t}$,

$\quad\quad CPI_{us,t}$ = U.S. CPI at time, t.

The alternative measures, Y and Y', were employed in both aggregate and per capita terms in the analysis.

Energy Consumption

Total energy consumption $(Q_{i,t})$ was derived from data on final consumption of coal, lignite, petroleum products, natural gas, hydroelectricity, and nuclear electricity, as reported in the U.N. *Statistical Yearbook*.[11] We converted all energy sources to barrels of oil equivalent by using conversion factors from the World Oil Industry, *British Petroleum Statistical Review*, 1975, and from the WAES report.[12]

Consumption of oil and oil products, $Q'_{i,t}$, as distinct from total energy consumption, was calculated as follows:

$\quad\quad Q'_{i,t}$ = indigenous oil production + imports − oil exports − bunkers
$\quad\quad\quad$ (in millions of barrels of oil).[13]

Q_t and Q'_t were measured both in gross and per capita terms.

In 1976, oil consumption by the 77 countries included in our data set accounted for 78.6 percent, or 4.4 MB/D, of total oil consumption (5.6 MB/D) by all 124 non-OPEC less-developed countries.

Sample Countries

The 77 NOLDCs in our sample are listed by region in Table 5. The numbers indicate whether the country belongs to the upper-income (1), medium-income (2), or lower-income (3) level, according to the World Bank's categories.[14] The 23 countries, for which the "own price" measure $(P''_{i,t})$ could be calculated, are indicated by an asterisk (*).

Although some values are missing from the data set, the raw data have been adjusted to make them as nearly comparable as possible. They can also be updated by the methods described above.

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[10]GNP data, instead of GDP, were used for the following countries: Burundi, Central African Republic, Chad, Congo, Mali, Mauritania, Niger, Somalia, Upper Volta, Bahrain, Yemen Democratic Republic, and Afghanistan. (See the U.N. *Statistical Yearbook* and the International Monetary Fund, *International Financial Statistics*, various issues, 1974-1978.)

[11]The measure of energy consumption that we use thus refers to *delivered* energy (energy delivered to the final consumer) rather than to *primary* energy (the energy content of fuels before they are processed or converted). Typically, primary energy is about 5 to 7 percent greater than delivered energy for the less-developed countries.

[12]Workshop on Alternative Energy Scenarios, *Energy: Global Prospects, 1985-2000*, 1977, pp. 10, 11.

[13]The data are taken from *World Energy Supplies*, U.N. Series J, 1976, 1977, 1978. In this data series, indigenous production plus imports already includes bunkers.

[14]Lambertini, op. cit. Taiwan has been included in our NOLDC data set even though it is omitted from the UN sources. As an energy consumer, it ranks among the 6 largest of the 77 countries. As defined by the World Bank, annual per capita income (in 1972 dollars) is below $200 for lower-income countries, between $200 and $375 for medium-income countries, and above $375 for upper-income countries.

Table 5

SAMPLE COUNTRIES

Africa	Income Level	Middle East	Income Level	Asia	Income Level	Latin America	Income Level
Benin	3	Bahrain	1	Afghanistan	3	Argentina*	1
Burundi	3	Jordan*	2	Bangladesh	3	Bahamas	1
Cameroon	2	Lebanon	1	Burma	3	Barbados	1
Central African Republic	3	Syria*	2	Cyprus	1	Bolivia	2
Chad	3	Yemen Arab Republic	3	Fiji*	1	Brazil*	1
Congo*	2	Yemen Democratic Republic	3	India*	3	Colombia*	1
Egypt	2			Korea*	2	Costa Rica	1
Ethiopia	3			Malaysia*	1	Dominican Republic	1
Gambia	3			Nepal	3	El Salvador	2
Ghana*	2			Pakistan*	3	Guatemala	1
Ivory Coast*	2			Philippines*	2	Guyana	1
Kenya*	3			Singapore	1	Haiti*	3
Liberia	2			Sri Lanka	3	Honduras	2
Madagascar	2			Taiwan*	1	Jamaica*	1
Malawi	3			Thailand*	2	Malta	1
Mali	3					Mexico	1
Mauritania	3					Netherlands Antilles	1
Mauritius	2					Nicaragua*	1
Morocco*	2					Panama	1
Niger	3					Paraguay	2
Rwanda	3					Peru	1
Sierra Leone	3					Surinam	1
Senegal	2					Trinidad-Tobago*	1
Somalia	3					Uruguay	1
Sudan	3						
Tanzania*	3						
Togo	3						
Tunisia*	1						
Uganda	3						
Upper Volta*	3						
Zaire*	3						
Zambia	1						

*Countries for which the "own price" measure ($P''_{i,t}$) could be calculated.

Notwithstanding its manifest shortcomings, the combined cross-section and time-series data set for the 77 NOLDCs, covering all the previously mentioned variables, deflations, conversions, and other adjustments, is a unique and valuable product of this study.

ESTIMATION OF INCOME AND PRICE ELASTICITIES

We will now describe the results that we obtained by fitting the linear regression models, described earlier, to the logarithms of oil consumption and total energy consumption for the 1967-1976 period. As discussed under "Methods and Models" at the beginning of this chapter, the models were varied along several dimensions: country groupings; the different speeds with which consumption (demand) adjusts to income changes; differing definitions of variables; etc. Table 6 lists these dimensions and identifies the various combinations employed in the regressions. Appendix B contains the complete set of regression equations, t-statistics, and measures of fit corresponding to those combinations.

Table 6

DIMENSIONS OF VARIATION IN REGRESSION MODEL

Dimension	Description
1. Country groupings	a. All 77 NOLDCs b. New industrial countries (Argentina, Brazil, Korea, Mexico, Taiwan) c. High-income countries (n = 28) d. Middle-income countries (n = 19) e. Low-income countries (n = 30) f. Countries for which actual ("own") price data were available (n = 23)
2. Speed of adjustment to income changes	a. Delayed (model 1) b. Immediate (model 2)
3. Country-specific dummy variables	a. Absent b. Included
4. Definitions of variables	a. Price defined two ways: deflated Ras Tanura; or "own price," if available (see text discussion under "Oil Price Data") b. GDP defined two ways: converted to U.S. dollars and then deflated; or deflated and then converted to dollars (see text discussion under "Gross Domestic Product") c. Demand (consumption defined two ways: oil consumption; and total energy consumption)
5. Per capita or aggregate	a. Consumption and GDP divided by population b. Aggregate consumption and aggregate GDP
6. Time trend variable	a. Absent (in models without country dummy variables) b. Included (in models with country dummies)

Tables 7 and 8 summarize the range of coefficient values, and the associated ranges of short-, medium-, and long-run income and price elasticities of demand for oil, and for all commercial energy sources, covering the entire group of 77 NOLDCs in our data set. Appendix C shows the corresponding results (pertaining to oil demand only) for several subsets of these countries: high-income, medium-income, and low-income NOLDCs; five of the "new industrial countries" (Brazil, Mexico, Argentina, Korea, and Taiwan); and the 23 NOLDCs for which country-specific ("own") price data are available on oil import prices.

Several points about Tables 7 and 8 are worth noting:

1.   The range spanned by the income and price elasticities is extraordinarily wide. For example, short-run income elasticities of demand for oil differ by a factor of 3 [0.017 is the minimum value for model (1) and 0.059 is the maximum, without country dummy variables], depending on which combination of the various dimensions listed in Table 4 is used. For the model with country dummies and with the time trend variable, the range is even wider: the minimum short-run income elasticity is 0.012 and the maximum is .226.

For the price elasticities shown in Table 8, the range of the estimates is narrower: between −0.037 and −0.081 for the short-run price elasticities of demand for oil. Thus, the range of our elasticity estimates is much wider than that reported in previous work. (See Table 3, above.) This difference is explained (a) by the numerous dimensions over which we tested model variations (see Table 6) and (b) by the several types of elasticity measures for which results are reported (see point 3, below).

2.   Our estimates also show income elasticities of demand for oil that are considerably lower than those estimated in previous studies, although our price elasticities are similar to previous estimates. The range of our income elasticities is between 0.012 and 0.246 in the short-run, whereas previous estimates ranged between 0.40 and 1.19. For the long-run (1990), our income elasticities range between 0.024 and 0.663; those of previous studies varied between 0.32 and 1.86. Our estimates of price elasticities of demand for oil are between −.037 and −.081 in the short-run, compared with previous estimates, which were between −.05 and −.11. And our long-run (1990) price elasticity estimates vary between −.089 and −.761, compared with those of previous studies, which were between −.13 and −.50. (See Table 3, above.)

3.   The apparently simple question "What is the income (or price) elasticity of demand for oil or energy in the NOLDCs?" admits of neither a simple nor a singular answer. The answer depends on the type of elasticity that one is interested in, especially the time horizon of the elasticity. Tables 7 and 8 show four types that are defined more precisely in the footnotes accompanying the tables: short-run, medium-run, and long-run elasticities,[15] and the elasticities realized by 1990. The spread of our estimates across these four types of elasticities is very large for any specific model and combination of other special variations. Even when country

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[15]Moreover, the "long-run" may be very long, as well as widely variable in duration. For example, when the lag factor, λ, in models (1) and (2) is less than .8, more than 90 percent of the total "long-run" adjustment of demand to price and income changes will take place within 10 years. But when, as in many of our regression estimates, the estimate for λ rises above .9, a period longer than 30 or 40 years would be required to realize the bulk of the theoretically predicted "long-run" adjustment of demand! (See Appendix D for a fuller treatment of this problem.)

Table 7

RANGE OF INCOME ELASTICITIES RESULTING FROM MODEL VARIATIONS[a]

Country Dummy Variables	Adjustment to Income Change	Short-Run Income Elasticity[b]		Medium-Run Income Elasticity[c]		Long-Run Income Elasticity[d]		Income Elasticity Realized by 1990[e]	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
A. Oil Demand: 77 NOLDCs									
Absent	Delayed; model (1)	0.017	0.059	0.621	0.881	1.225	1.715	0.217	0.663
	Immediate; model (2)	0.069	0.249	0.641	0.871	1.154	1.636	0.259	0.653
Present[f]	Delayed; model (1)	0.012	0.144	0.018	0.200	0.024	0.256	0.024	0.256
	Immediate; model (2)	0.053	0.226	0.024	0.206	-0.005	0.187	-0.005	0.187
B. Total Energy Demand: 77 NOLDCs									
Absent	Delayed; model (1)	0.016	0.061	0.524	0.878	1.033	1.696	0.200	0.677
	Immediate; model (2)	0.065	0.242	0.538	0.851	1.010	1.459	0.245	0.670
Present[f]	Delayed; model (1)	0.009	0.155	0.015	0.244	0.022	0.332	0.022	0.332
	Immediate; model (2)	0.052	0.201	0.021	0.248	-0.009	0.324	-0.009	0.324

[a] The figures shown in panels A and B cover the intervals between minimum and maximum values resulting from the model variations described in the text and summarized in Table 6. For oil demand, variations in the models cover aggregate and per capita demand (consumption), as well as the differing definitions of income and price variables described above. For total energy demand, model variations cover the same items, but the only price variable used is the Ras Tanura price in constant 1970 dollars.

[b] Figures show the range of the regression estimates for the combined parameters $\alpha(1 - \lambda)$ in model (1), and for the parameter α_1 in model (2). All coefficients for the oil regressions (panel A) are statistically significant at a level of 2.5 percent or less. For the total energy regressions (panel B), the only coefficient not significantly different from zero is the minimum short-run elasticity shown for model (1), 0.016. All other short-run elasticities are significant at a 5-percent level or less.

[c] Calculated as the arithmetic average of the short-run and long-run income elasticities. (See A. Lambertini, *Energy and Petroleum in Non-OPEC Developing Countries, 1974-1980*, World Bank Staff Working Paper No. 229, Washington, D.C., 1976, p. 6.)

[d] Calculated by dividing the short-run income elasticity, in model (1), by $(1 - \lambda)$. For model (1), α is the long-run elasticity. For model (2), $(\alpha_1 + \alpha_2)/(1 - \lambda)$ is the long-run elasticity (see footnote e below).

[e] Defined as the predicted percentage change in the 1990 demand resulting from an income change of 1 percent in 1977, with constant income, as well as price, thereafter. The figures shown in panels A and B are calculated recursively. For model (1), the estimated parameter values for α, β, and λ are used, together with the assumed initial percentage increase in income, to calculate oil demand in period t. The demand is then used, with the same parameter values, to calculate demand in t + 1, and so on. Recursive estimation of the specification shown for model (2) results in a realized income elasticity, after n years, given by the following expression: $(\alpha_1 + \alpha_2)(1 - \lambda^n)/(1 - \lambda) - \alpha_2 \lambda^{n-1}$, where α_2 is the coefficient of the lagged income variable as discussed in the text. As n approaches infinity, this elasticity expression reduces to $(\alpha_1 + \alpha_2)/(1 - \lambda)$. The elasticities shown for 1990 are calculated from the year 1977; hence, n = 13.

[f] A time-trend variable is included in these models.

Table 8

RANGE OF PRICE ELASTICITIES RESULTING FROM MODEL VARIATIONS[a]

Country Dummy Variables	Adjustment to Income Change	Short-Run Price Elasticity[b]		Medium-Run Price Elasticity[c]		Long-Run Price Elasticity[d]		Price Elasticity Realized by 1990[e]	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
		A. Oil Demand: 77 NOLDCs							
Absent	Delayed; model (1)	-0.059	-0.041	-2.189	-0.620	-4.320	-1.199	-0.756	-0.467
	Immediate; model (2)	-0.059	-0.037	-2.185	-0.637	-4.311	-1.237	-0.761	-0.427
Present[f]	Delayed; model (1)	-0.081	-0.049	-0.115	-0.069	-0.149	-0.089	-0.149	-0.089
	Immediate; model (2)	-0.077	-0.050	-0.110	-0.071	-0.143	-0.092	-0.143	-0.092
		B. Total Energy Demand: 77 NOLDCs							
Absent	Delayed; model (1)	-0.045	-0.036	-1.629	-0.528	-3.213	-1.020	-0.572	-0.407
	Immediate; model (2)	-0.046	-0.032	-1.541	-0.512	-3.037	-0.992	-0.577	-0.370
Present[f]	Delayed; model (1)	-0.071	-0.060	-0.118	-0.096	-0.164	-0.130	-0.164	-0.130
	Immediate; model (2)	-0.067	-0.060	-0.108	-0.096	-0.150	-0.131	-0.150	-0.130

[a]The figures shown in panels A and B cover the intervals between minimum and maximum values resulting from the model variations described in the text and summarized in Table 6. For oil demand, variations in the models cover aggregate and per capita demand (consumption), as well as the differing definitions of income and price variables described above. For total energy demand, model variations cover the same items, but the only price variable used is the Ras Tanura price in constant 1970 dollars.

[b]Figures show the range of the regression estimates for the combined parameters $\beta(1 - \lambda)$ in models (1) and (2). When the country dummy variables are absent, all of the short-run (negative) elasticity coefficients are significant at the .005 level, for both the oil regressions (panel A) and the total energy regressions (panel B).

[c]Calculated as the arithmetic average of the short-run and long-run price elasticities. (See A. Lambertini, *Energy and Petroleum in Non-OPEC Developing Countries, 1974–1980*, World Bank Staff Working Paper No. 229, Washington, D.C., 1976, p. 6.)

[d]Calculated by dividing the short-run price elasticity, in model (1), by $(1 - \lambda)$. For model (1), β is the long-run elasticity.

[e]Defined as the predicted percentage change in the 1990 demand resulting from a price change of 1 percent in 1977, with constant prices, as well as income, thereafter. The figures shown in panels A and B are calculated recursively, as described in footnote e to Table 7.

[f]A time-trend variable is included in the models.

dummy variables, which tend to reduce the range of the coefficients, are present in the regressions, the spread often covers a factor of five or more across the four types of elasticities.

4.   Tables 7 and 8 show the important effects of country dummy variables on the results. When dummy variables are omitted, relatively large coefficients on the lagged variables for oil or energy consumption result (i.e., $\lambda \geq .9$), thereby generating extremely high long-term price and income elasticities, for reasons described earlier. (See the discussion under "Methods and Models," above.)

For the other country groupings, the estimated range of price and income elasticities for oil demand is shown in Appendix C. With only minor exceptions, the coefficients for these groupings show a pattern similar to that of the all-country category. When the coefficients for the country subcategories are significantly different from zero, they have the same (predicted) signs as the corresponding coefficients for the all-country regressions. Income elasticities tend to be slightly higher for middle-income countries than for the other groupings, whereas for the higher-income countries, the price elasticities tend to be slightly lower. The absolute magnitudes of long-run elasticities, for both income and price, are somewhat lower for the country subgroupings than for the 77 NOLDCs because the coefficients on lagged consumption tend to be smaller.

FORECASTS OF OIL DEMAND, 1980-1990

Forecasts for the oil demand of all NOLDCs were made through 1990 for each of the model variations described above. For reasons already mentioned, we thought it especially important to record forecast uncertainties. This practice has not been followed in the previous work on energy demand in NOLDCs referred to in Chapter 2.

The uncertainties we report arise from the randomness of future data, as well as from the discrepancies between estimated and true values of population parameters (i.e., the errors in the regression coefficients of the independent variables.)[16] Demand forecasts are reported both with and without dummy variables because of (a) the statistical significance of the two sets of results and (b) the contrasting predictions they provide.[17]

The statistical procedures required to make the point forecasts for the NOLDCs are simple: (1) We assume particular growth patterns ("scenarios") for price, income, and population through 1990. (2) We assume a constant population growth rate of 2.7 percent per year, but we vary prices (by a 3-percent and 5-percent increase per year) and income (by a 3-, 5-, and 7-percent increase per year).[18] (3) We include a time variable, which assumes values between 1 and 14 (for 1976-1990), in the regressions with country dummy variables. (See the discussion of time trends

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[16]The standard errors of the forecasts, together with the mean values, are shown in Tables 9 and 10 on pages 24 and 26.

[17]Statistical tests were conducted on the importance of country-specific dummy variables. They appear to be statistically significant in all cases, yielding F-statistics beyond the 0.001 significance level.

[18]These numbers were chosen to provide comparability with the forecasts of Choe, op cit. Assuming a 1979 oil price of $18 per barrel, annual increases of 3 percent and 5 percent would lead to 1990 oil prices of $25 and $31 per barrel, respectively, in constant 1979 dollars.

earlier in this chapter.) (4) Using the regression equations and data up to the present (i.e., 1976), we predict demand a single year in advance. We can then use this forecast to predict the next year's value, and so on. The procedure, known as "chain forecasting," is a standard method of time series analysis.

The forecasts are initially obtained in logarithmic units; they are exponentiated, corrected for bias in the standard manner,[19] and summed over countries to yield estimated totals. The standard errors of the estimated totals are easily computed, since the forecasts are simply sums of independent lognormal random variables. In reporting confidence intervals below, we assume that the estimated totals have an approximate lognormal distribution.

Table 9, based on the regression coefficients in Appendix B, shows the oil demand predictions for 1980, 1985, and 1990 under two of the growth scenarios described above: one assumes a slow income growth in the NOLDCs of 3 percent and a rapid oil price increase of 5 percent annually; the other assumes a rapid income growth of 7 percent and a slow price increase of 3 percent annually.[20] Forecasts for the other combinations of income growth and price growth are shown in Appendix Tables B.3, B.4, and B.5. The data in our sample cover 77 out of a total of 124 NOLDCs. Since the 77 countries accounted for 79 percent, or 4.4 MB/D, of oil consumption by all NOLDCs in 1976, the figures shown in Table 9 have been scaled proportionally upward (multiplied by 1.27) to represent corresponding predictions for all NOLDCs.

There are several sources of variation in our 1990 oil demand forecasts: (1) differing scenarios pertaining to income growth and price growth; (2) differing model forms; (3) differing definitions of variables; and (4) forecast standard errors. These sources interact with one another. For models without dummy variables, the scenarios with rapid (7 percent) income and slow (3 percent) price growth differ substantially from the scenarios with slow (3 percent) income and rapid (5 percent) price growth—i.e., by 43 percent. For the models that have dummy variables, the differing growth scenarios have a smaller effect on the forecasts: 34 percent. Per capita models with dummy variables yield slightly higher forecasts than aggregate models with dummy variables; but when dummy variables are absent, the forecasts for per capita models and aggregate models are about the same.

Forecast standard errors are large (about 15 percent) for models without dummy variables and small (about 5 percent) for those with dummy variables; this implies 95-percent probability intervals that vary by about 30 percent and 10 percent of the forecast values, respectively. Consequently, greater confidence should be placed in the forecasts that use country dummies. As explained earlier, these are also the forecasts that make specific allowance for the effect of time on oil and energy consumption.

Differences in the definition of income and price variables provide another source of substantial variation in the forecasts. The mean values of the forecasts may change by more than 53 percent when variable definitions change while scenarios and model forms are held constant. For example, in the 7-percent-income-growth, 3-percent-price-growth scenario, with dummy variables included, Table 9

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[19]If log y has a normal distribution, mean U, and variance V, $E(y) = \exp(U + .5V)$.

[20]We selected these two scenarios from the six income-and-price combinations described in the text because we believe that they cover the most policy-relevant cases.

Table 9

OIL DEMAND FORECASTS TO 1990: ALL COUNTRIES

Country Dummy Variables	Adjustment to Income Change	Dependent Variable Form	Growth Rates (%) GDP	Growth Rates (%) Price	Oil Demand (MB/D) Actual, 1976	Forecast 1980	Forecast 1985	Forecast 1990	Oil Demand Forecast Standard Errors[a] 1980	Oil Demand Forecast Standard Errors[a] 1985	Oil Demand Forecast Standard Errors[a] 1990	Oil Demand (MB/D) Range of Forecasts Due to Definition of Variables 1980	Oil Demand (MB/D) Range of Forecasts Due to Definition of Variables 1985	Oil Demand (MB/D) Range of Forecasts Due to Definition of Variables 1990
Absent	Delayed; model (1)	Aggregate	3 / 7	5 / 3	5.60 / 5.60	6.49 / 6.71	7.47 / 8.37	8.24 / 10.41	0.63 / 0.65	0.97 / 1.09	1.27 / 1.60	6.10-6.49 / 6.30-6.71	6.41-7.47 / 7.13-8.37	6.33-8.24 / 7.89-10.41
		Per capita	3 / 7	5 / 3	5.60 / 5.60	6.39 / 6.73	7.23 / 8.57	7.85 / 11.04	0.61 / 0.64	0.90 / 1.06	1.12 / 1.58	6.06-6.39 / 6.26-6.73	6.29-7.23 / 7.05-8.57	6.13-7.85 / 7.76-11.04
	Immediate; model (2)	Aggregate	3 / 7	5 / 3	5.60 / 5.60	6.37 / 6.73	7.19 / 8.41	7.83 / 10.45	0.60 / 0.64	0.90 / 1.06	1.16 / 1.55	6.02-6.37 / 6.26-6.73	6.21-7.19 / 7.03-8.41	6.03-7.83 / 7.71-10.45
		Per capita	3 / 7	5 / 3	5.60 / 5.60	6.29 / 6.74	7.00 / 8.51	7.53 / 10.79	0.59 / 0.63	0.85 / 1.04	1.06 / 1.52	5.94-6.29 / 6.20-6.74	6.02-7.00 / 6.88-8.51	5.73-7.53 / 7.47-10.79
Present[b]	Delayed; model (1)	Aggregate	3 / 7	5 / 3	5.60 / 5.60	7.08 / 7.35	9.59 / 10.49	13.01 / 14.97	0.30 / 0.31	0.40 / 0.44	0.55 / 0.63	7.08-7.30 / 7.19-7.55	9.59-10.37 / 10.02-11.16	13.01-14.75 / 13.98-16.51
		Per capita	3 / 7	5 / 3	5.60 / 5.60	7.14 / 7.46	9.76 / 10.80	13.35 / 15.65	0.30 / 0.31	0.40 / 0.45	0.55 / 0.65	7.14-7.38 / 7.28-7.67	9.76-10.61 / 10.30-11.52	13.35-15.27 / 14.57-17.31
	Immediate; model (2)	Aggregate	3 / 7	5 / 3	5.60 / 5.60	7.12 / 7.36	9.75 / 10.50	13.36 / 15.01	0.30 / 0.31	0.41 / 0.44	0.56 / 0.63	7.07-7.30 / 7.13-7.56	9.68-10.33 / 9.83-11.20	13.25-14.64 / 13.59-16.60
		Per capita	3 / 7	5 / 3	5.60 / 5.60	7.20 / 7.46	9.99 / 10.82	13.87 / 15.70	0.30 / 0.31	0.41 / 0.45	0.57 / 0.65	7.14-7.39 / 7.22-7.68	9.88-10.61 / 10.13-11.58	13.68-15.24 / 14.20-17.45

NOTE: Projections assume a steady population increase of 2.7 percent per year and percentage rates of GDP growth and price growth as indicated.

[a]Approximate standard errors were chosen so that [forecast] +/- [standard error] nearly equals the interval obtained by exponentiating the logarithmic prediction interval.

[b]A time-trend variable is included in these forecasts.

shows a 1990 forecast for a single model [model (2)] that varies by 23 percent (between 14.20 and 17.45 MB/D) as a result of changes in definition of the variables. By contrast, the two model variations that we employed had a much more limited effect on the forecasts: For example, with dummy variables excluded and the income-and-price scenario held constant, the maximum difference between the forecasts of model (1) and model (2) is only 5 percent [7.83 MB/D in the aggregate version of model (1) *versus* 8.24 MB/D in the aggregate version of model (2)] when the definition of variables is unchanged.

Table 9 also shows that the 1990 forecasts for models with country dummies are 50- to 60-percent higher than those for the corresponding models without the dummy variables. This difference is principally explained by the inclusion of the time-trend variable in the former case. The time-trend variable has the effect of adding between 2.3 percent and 4.3 percent annually to the forecasts, independent of the effects of price and income changes. A further effect of this variable is to reduce the income elasticities and raise the (negative) price elasticities from their values in the regressions without dummy variables. (See Tables 7 and 8 above.)

These observations suggest the substantial uncertainty that exists about 1990 oil demand. Price and income growth prospects in the NOLDCs are quite unclear, yet they have potentially large effects on what will occur. Uncertainty also arises from the possible choices among model specification and variable definitions; the 1990 forecasts resulting from these choices vary considerably.

A basic implication of these results is that policy formulation should take this uncertainty explicitly into account, a point to which we will return later.

SIZING THE DEMAND FORECASTS

How large will the energy demand of the NOLDCs be in the next decade and how significantly will it affect the world energy market?

The question is, to paraphrase Churchill, a riddle wrapped in an enigma. Several types of uncertainty becloud the answer: (a) uncertainty relating to the models, variables, and data that are endogenous to the forecasting methodology itself; (b) uncertainty relating to the economic growth and price scenarios that are assumed to confront the NOLDCs independently of the forecasting methodology; and (c) uncertainty concerning the size and characteristics of world energy demand, of which NOLDC demand will be a part.

The results of these nested uncertainties are summarized in Table 10 for the 7-percent income growth and 3-percent oil price increase scenario, and for the 3-percent income growth and 5-percent price increase scenario.

Panel A in Table 10 shows how the standard errors associated with each model variation affect the forecasts when the definition of variables is held constant. Panel B shows the effect on the mean value of the forecasts when the definition of variables is changed without allowing for standard errors.

Table 10 may be clarified by an explanation of several points:

1. The first three columns embrace the uncertainties referred to in comment (a) directly above; columns (4) and (5) reflect comment (b); the remainder of the table reflects uncertainties referred to in comment (c), above.

Table 10

PERCENTAGE RANGE OF NOLDC OIL DEMAND FORECASTS

(1) Country Dummy Variables	(2) Adjustment to Income Change	(3) Dependent Variable Form	Growth Rates (%) (4) GDP	(5) Price	Range of Forecasts and Share of World[a] Demand for 1990[b] (6) MB/D	(7) Percent (WAES)	(8) Percent (Eden)
A	A. Range Due to Forecast Standard Errors						
Absent	Delayed; model (1)	Aggregate	3	5	7.07- 9.61	10-13	13-18
			7	3	8.93-12.14	12-16	17-23
		Per capita	3	5	6.81- 9.06	9-12	13-17
			7	3	9.57-12.73	13-17	18-24
	Immediate; model (2)	Aggregate	3	5	6.75- 9.07	9-12	13-17
			7	3	9.02-12.11	12-16	17-22
		Per capita	3	5	6.54-8.66	9-12	12-16
			7	3	9.38-12.41	13-17	17-23
Present	Delayed; model (1)	Aggregate	3	5	12.47-13.57	17-18	23-25
			7	3	14.35-15.61	19-21	27-29
		Per capita	3	5	12.81-13.92	17-19	24-26
			7	3	15.01-16.31	20-22	28-30
	Immediate; model (2)	Aggregate	3	5	12.81-13.92	17-19	24-26
			7	3	14.39-15.65	19-21	27-29
		Per capita	3	5	13.31-14.46	18-19	25-27
			7	3	15.07-16.36	20-22	28-30
B	B. Range Due to Definition of Variables						
Absent	Delayed; model (1)	Aggregate	3	5	6.33- 8.24	9-11	12-15
			7	3	7.89-10.41	11-14	15-19
		Per capita	3	5	6.13- 7.85	8-11	11-15
			7	3	7.76-11.04	10-15	14-20
	Immediate; model (2)	Aggregate	3	5	6.03- 7.83	8-11	11-15
			7	3	7.71-10.45	10-14	14-19
		Per capita	3	5	5.73- 7.53	8-10	11-14
			7	3	7.47-10.79	10-15	14-20
Present	Delayed; model (1)	Aggregate	3	5	13.01-14.75	18-20	24-27
			7	3	13.98-16.51	19-22	26-31
		Per capita	3	5	13.35-15.27	18-21	25-28
			7	3	14.57-17.31	20-23	27-32
	Immediate; model (2)	Aggregate	3	5	13.25-14.64	18-20	25-27
			7	3	13.59-16.60	18-22	25-31
		Per capita	3	5	13.68-15.24	18-21	25-28
			7	3	14.20-17.45	19-24	26-32

NOTE: Projections assume a steady population increase of 2.7 percent per year, and percentage rates of GDP growth and price growth as indicated. The figures under the columns labeled "WAES" and "Eden" show our NOLDC forecasts as a percentage of the 1990 world oil consumption estimates made in those studies (see Table 3, above).

[a] Excluding centrally planned economies.

[b] OECD did not make a forecast of NOLDC demand in 1990 (see Table 3, above).

2. Table 10 presents the results of our study in a form that roughly parallels the results of the other studies referenced in Table 2, above. Tables 10 and 2 can thus be usefully examined together.

3. In Panel B of Table 10, columns (7) and (8) show *NOLDC* oil demand for 1990 as a percentage of the *world* oil demand forecasted in the WAES and Eden studies cited in Table 2. For example, in 1990, *NOLDC oil demand—which we forecast as being between 5.73 MB/D and 17.45 MB/D*[21] *—may be as small a share of world oil demand as 8.0 percent, and as large a share as 32.2 percent,* if we assume the high (74 MB/D) WAES estimate of world oil consumption in calculating the minimum NOLDC share, and the low (54 MB/D) Eden estimate in calculating the maximum NOLDC share. The range of the NOLDC share in world demand narrows if the reverse assumption is made: 10.6 percent if world demand is assumed to be low when NOLDC demand is low; and 23.5 percent if world oil demand is assumed to be high when NOLDC demand is high. (See Table 3, above.) The previous forecasts, shown in Table 2, span a much narrower range—between 18.2 percent and 24.5 percent—because the types of uncertainty encompassed by these earlier studies are considerably more restricted than those we have addressed. (Note that our forecasted market shares for 1990 compare with the actual NOLDC share of world oil consumption in 1976 of 14.3 percent; see Table 1, above.)

4. If our NOLDC forecasts were expressed as a fraction of world *imports* of oil, rather than world oil consumption, the magnitudes would be larger: between 8.3 percent and 34.6 percent (assuming that the 1976 relationships between oil imports and oil consumption still prevail in 1990). The reason, as suggested by Table 1, above, is that virtually all NOLDC oil consumption is imported, whereas only three-quarters of world oil consumption is imported.

Table 10 can be simplified by confining the NOLDC growth and price scenarios in columns (4) and (5) to a single case. This is done in Table 11, which shows the NOLDC share of world oil demand in the 1980-1990 period for the scenario that is perhaps the most reasonable one: an annual economic growth in the NOLDCs of 5 percent (aggregate and per capita), and oil-price increases at the same rate. For the central scenario shown in Table 11, NOLDC oil demand in 1990—which we forecast as being between 6.10 MB/D and 16.03 MB/D—may be as small a fraction of forecasted world oil demand as 8.0 percent, and as large a fraction as 30.0 percent.

Finally, we want to size our forecasts of NOLDC oil demand in relation to those made by the World Bank (Lambertini-Gordian) study of 1976.[22] For this purpose, we use the same growth and price scenarios that were assumed by Lambertini (namely, NOLDC growth rates of 5 percent annually, and a constant real price of

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[21]As noted in the text, forecast standard errors would add between 10 percent and 30 percent to this range.

[22]Gordian Associates, *Requirements for Financing Energy Development in Non-OPEC Less-Developed Countries Through 1990,* 1976. The later World Bank study by Choe dealt with total energy demand, without making separate estimates for oil.

Table 11

PERCENTAGE RANGE OF NOLDC OIL DEMAND FORECASTS: CENTRAL CASE SCENARIO

(1) Country Dummy Variables	(2) Adjustment to Income Change	(3) Dependent Variable Form	Growth Rates (%)		Range of Forecasts and Share of World[a] Demand for 1990[b]		
			(4) GDP	(5) Price	(6) MB/D	(7) Percent (WAES)	(8) Percent (Eden)
A. Range Due to Forecast Standard Errors							
Absent	Delayed; model (1)	Aggregate	5	5	7.57–10.29	10–14	14–19
		Per capita	5	5	7.73–10.28	10–14	14–19
	Immediate; model (2)	Aggregate	5	5	7.47–10.04	10–14	14–19
		Per capita	5	5	7.53– 9.97	10–13	14–18
Present	Delayed; model (1)	Aggregate	5	5	13.22–14.38	18–19	25–27
		Per capita	5	5	13.71–14.90	18–20	25–28
	Immediate; model (2)	Aggregate	5	5	13.42–14.58	18–20	25–27
		Per capita	5	5	14.00–15.20	19–20	26–28
B. Range Due to Definition of Variables							
Absent	Delayed; model (1)	Aggregate	5	5	6.59– 8.83	9–12	12–16
		Per capita	5	5	6.43– 8.92	9–12	12–17
	Immediate; model (2)	Aggregate	5	5	6.36– 8.66	9–12	12–16
		Per capita	5	5	6.10– 8.66	8–12	11–16
Present	Delayed; model (1)	Aggregate	5	5	13.51–15.07	18–20	25–28
		Per capita	5	5	13.99–15.66	19–21	26–29
	Immediate; model (2)	Aggregate	5	5	13.24–15.32	18–21	25–28
		Per capita	5	5	13.76–16.03	19–22	26–30

NOTE: Projections assume a steady population increase of 2.7 percent per year, and percentage rates of GDP growth and price growth as indicated.

[a]Excluding centrally planned economies.

[b]OECD did not make a forecast of NOLDC demand in 1990. (See Table 3, above.)

oil in the world market). For the comparison, we use the version of our model corresponding to that used by Lambertini: country dummy variables are absent; adjustment to income changes is assumed to be long-term [hence, model (1) is used]; and oil demand is expressed in per capita, rather than aggregate, terms.

The comparison between our forecasts and those of Lambertini-Gordian are summarized in Table 12. As Table 12 indicates, the two sets of forecasts are remarkably similar in one respect, and significantly different in another. The mean values of our forecasts for each year—1980, 1985, and 1990—differ by less than 10 percent from the World Bank estimates. However, our estimates show a range of uncertainty between the upper and lower forecasts in each year that rises from 30 percent in 1980 to 52 percent in 1985, and reaches 77 percent in 1990. Of course, when the

Table 12

COMPARISON OF NOLDC OIL DEMAND FORECASTS: PRESENT RAND STUDY
AND WORLD BANK (LAMBERTINI-GORDIAN)[a]

		NOLDC Oil Demand Forecasts (MB/D)					
		1980		1985		1990	
Assumed Growth Rates (%)[b]		World Bank	Rand	World Bank	Rand	World Bank	Rand
GDP	Oil Prices						
5	0	6.17	6.12-7.48	7.80	7.63-9.70	10.0	9.70-12.84

[a]Our estimating equation omits country dummy variables, assumes that adjustment to income change is delayed [i.e., model (1)], and expresses oil demand in per capita terms.

[b]For the original World Bank forecasts, Lambertini assumed a GDP annual growth rate for upper- and middle-income LDCs of 5.5 percent, and for lower-income LDCs of 4.5 percent. Oil prices were assumed to be constant in real terms, or declining (sic!). As noted earlier, the original World Bank forecasts reached to 1980, and were extended to 1985 and 1990 by Gordian Associates; see Table 2, above.

other growth/price scenarios are taken into account, as well as the other variations in the models and variables that we have used, the range of our forecasts diverges substantially from the World Bank estimates.

Chapter 4

IMPLICATIONS AND CONCLUSIONS

Our principal forecasts of NOLDC oil consumption, compared with those of other studies, are summarized in Table 13. As noted earlier, the figures shown in Table 13 reflect the numerous scenarios of income growth and oil price increases that we have examined, as well as the other variations in our estimation methods. If, instead, we focus on a single scenario that is perhaps the most reasonable and likely case—namely, one involving an assumed NOLDC growth rate of 5 percent

Table 13

FORECASTS OF AMOUNTS AND SHARES OF NOLDC OIL CONSUMPTION IN 1990

NOLDC Oil Consumption in 1990	Amounts and Shares	
	Rand Forecasts	Previous Forecasts
Total oil consumption	5.7–17.4 MB/D	10.0–13.5 MB/D
Consumption as a share of world oil consumption[a]	7.8–32%	14.4–24.5%
Imports as share of world oil imports[b]	8.3–34.6%	15.5–26.5%

[a] World oil consumption is assumed to be 54 MB/D or 74 MB/D in 1990 according to the Eden and WAES estimates, respectively (see Table 3, above).

[b] NOLDC oil imports are assumed to be the same fraction of NOLDC consumption in 1990 as in 1976:

$$\left(\frac{\text{NOLDC imports 1976}}{\text{NOLDC consumption 1976}} = \frac{4.7}{5.6} = .84 \right)$$

(see Table 1). Consequently, NOLDC imports in 1990 are estimated to be between 4.8 and 14.6 MB/D. World oil imports are assumed to be the same fraction of world consumption in 1990 as in 1976:

$$\left(\frac{\text{world imports 1976}}{\text{world consumption 1976}} = \frac{30.6}{39.2} = .78 \right).$$

Consequently, world oil imports in 1990 are estimated to be between 42.2 and 57.8 MB/D.

annually and oil price increases at the same rate in real terms—the range of our forecasts narrows, as shown in Table 14.

It is worth noting that although the range of our forecasts is much wider than that of the previous forecasts, the *mid-points* of the two sets of estimates shown in Table 13 are almost identical: (a) the mid-point of forecasted NOLDC oil consumption in 1990 is 11.5 MB/D in our estimates as compared with 11.7 MB/D in

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Table 14

RAND FORECASTS OF NOLDC OIL CONSUMPTION IN 1990: CENTRAL SCENARIO

NOLDC Oil Consumption in 1990	Rand Forecast
Total oil consumption	6.1–16.0 MB/D
Consumption as share of world oil consumption[a]	8.2–29.6%
Imports as share of world oil imports[b]	8.8–31.8%

[a]World oil consumption is assumed to be 54 MB/D or 74 MB/D in 1990 according to the Eden and WAES estimates, respectively (see Table 3, above).

[b]NOLDC imports in the central scenario are estimated to be between 4.8 and 27.1 MB/D, based on the procedures described in Table 13, footnote b.

the previous forecasts; (b) NOLDC oil consumption in 1990 is 19.9 percent of world oil consumption in our estimates *versus* 19.5 percent in the previous estimates; and (c) the NOLDC share in world oil imports in 1990 is 21.5 percent in our estimates *versus* 21 percent in the previous estimates.

IMPLICATIONS FOR POLICY

The wide range of our forecasts for NOLDC oil demand in 1990 suggests that there is substantial uncertainty about all such forecasts. In addition to the standard errors of the forecasts (to be discussed later), there are three principal sources for this uncertainty: (1) differences in scenarios assumed for NOLDC economic growth and for world oil prices; (2) differences in model specifications; and (3) differences in the definition and measurement of variables used in the models. Among the three, differences in scenario assumptions and in the definition of variables have about equally large effects, whereas differences in model specification have the smallest.

Differences in the scenarios (covering the high-income-growth and slow-price-growth scenario, and the slow-income-growth and rapid-price-growth scenario) account for a 43-percent variation between the maximum and minimum 1990 forecasts when variable definitions and model specifications are held constant. Of course, this range would be widened further if the scenarios were expanded to allow for more extreme income growth and price scenarios that could be created by various political and technological contingencies: for example, contingencies due to political instability or disruption in the Middle East, or contingencies relating to new major oil discoveries or to technological breakthroughs or breakdowns in the development of synthetic fossil fuels.

As noted earlier, there are several plausible ways of measuring, deflating, and adjusting the income and price variables of the models. These alternatives are another major source of uncertainty. Differences in the definition and measurement of the price and income variables, while the scenarios and model specifica-

tions are held constant, account for a variation of more than 53 percent between the high and low forecasts for 1990.

By way of contrast, differences in model specification result in a maximum difference of only 5.2 percent between the estimates of model (1) and model (2) for any given scenario. This difference is raised substantially by including or excluding country dummy variables, and allowing for the effect of time when dummies are included.[1] These results relating to the differing sources of uncertainty, and their relative effects, are summarized in Table 15.

Table 15

MAXIMUM VARIATION DUE TO EACH SOURCE OF UNCERTAINTY

Source of Uncertainty	Maximum Variation (%)
Scenarios[a]	43.3
Definition of variables[b]	53.5
Model specification[c]	5.2

NOTE: Whenever the definition of variables is held fixed, GDP is defined as the average of the exchange rates in the 1969–1971 period; the oil price is defined as the "own" price paid by each individual country when these data are available, and as the Ras Tanura price otherwise. Tables 9 and 10 and Appendix Tables B.3 and B.4 are based on these definitions.

[a]Definitions of variables and the model are held constant. Maximum variation occurs with model (2) in per capita terms and excluding country dummies (see Appendix Table B.3). The 1990 forecast range attributable to the scenario variations lies between 7.53 MB/D in the low-income-growth (3-percent per annum) and high-price-growth (5-percent per annum) scenario and 10.79 MB/D in the high-income-growth and low-price-growth scenario.

[b]Scenarios and the model are held constant. Maximum variation occurs in the scenario with 7-percent GDP annual growth rate and 5-percent annual price increase, using model (2) in per capita terms without country dummy variables (see Appendix Table B.5).

[c]Scenarios and definitions of variables are held constant. Maximum variation occurs in the scenario with 3-percent GDP annual growth rate and 5-percent annual price increase, with models (1) and (2) expressed in aggregate terms, without dummies (see Appendix Table B.3).

Even these sources of uncertainty do not tell the whole story. Both the maxima and minima of these estimates should be extended to allow for the uncertainty of

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[1]In the scenario with 3-percent income growth and 5-percent price growth, the maximum demand forecast of model (2) with country dummy variables is 13.87 MB/D, whereas the corresponding forecast for model (1), *without* country dummies, is 7.85 MB/D, with models expressed in per capita terms. (See also the discussion of the time variable in Chapter 3.)

each estimate. As noted earlier, standard errors of the forecasts are larger for models without dummy variables (15 percent) than for models with them (5 percent). To provide confidence levels of 95 percent, an additional margin between 30 percent and 10 percent, respectively, should be added to the intervals between our upper and lower estimates of NOLDC oil demand in 1990.

What policy implications follow from these major uncertainties about NOLDC oil and energy demand in the next decade?

The most obvious answer is that policy plans and pronouncements should recognize the inevitably great uncertainty that must accompany efforts to forecast NOLDC oil and energy demand this far into the future. From the standpoint of U.S. energy policy, it may be wise to give greater attention to the forecasts based on high NOLDC income growth, and high income elasticity of NOLDC demand, combined with low price elasticity of NOLDC demand. If growth rates in the NOLDCs are reasonably high (7 percent or more) and energy price increases are low, NOLDC demand for oil may reach or exceed 17 MB/D in 1990. This means that the oil consumption of the NOLDCs would amount to more than 30 percent of world consumption, and that their oil imports would be nearly 35 percent of world imports. If rates of economic growth in the NOLDCs are at the 7-percent annual level and world oil prices are also rising steadily, NOLDC oil demand would still be fairly high, perhaps as high as 15 MB/D, or as much as 27 percent of world consumption and almost 30 percent of world imports.

The range of these forecasts suggests a dilemma for U.S. policy. Rapid growth and economic development in the NOLDCs—a general aim of U.S. *foreign* policy—especially if coupled with low price elasticity and high income elasticity of demand, will mean a rapidly growing NOLDC demand for oil and hence upward pressure on world oil prices and supplies—a situation that U.S. *energy* policy would prefer to avoid. Thus the aims of U.S. policy in the arena of North-South relations are in conflict with those in the international energy arena.

In principle, reconciliation between these differing U.S. policy interests may lie in our encouraging the NOLDCs to follow "soft energy paths" (i.e., solar, geothermal, biomass, and other renewable energy sources), as well as to develop fossil fuel resources. U.S. assistance that focuses on the development of these alternatives, not excluding nuclear power, will help to ease the conflict between U.S. energy policy and U.S. foreign policy vis-à-vis the LDCs. But these paths contain some pitfalls. Politically, the LDCs are likely to react with skepticism if not resentment toward the U.S. if we try to promote soft-energy development, as well as increased use of gas and coal, in the developing countries while continuing to expand our own oil consumption at home. Moreover, the promotion of nuclear power development in the LDCs may increase the major hazard of proliferation of nuclear weapons.

The conflict between these two dimensions of U.S. policy—energy policy, and foreign policy toward the "South"— is a real one. It may be a whimsical consolation to observe that the intensity of the conflict is likely to be eased by the limited effectiveness of U.S. policy efforts to accelerate the development of the LDCs or to restrain the international demand for oil. However, U.S. pronouncements in various international forums should at least be aware of, and sensitive to, the existence of this conflict.

The relationship between the NOLDCs and world oil markets may be viewed from a different, and more congenial, standpoint. Instead of looking at the effect

of NOLDC economic growth and oil demand on world markets, one may consider the effect of oil markets on the NOLDCs. When viewed from this standpoint, the energy policy of the U.S. and its foreign policy are highly compatible, and, more broadly, so are the interests of the U.S. and those of the NOLDCs.

In general, the NOLDCs and the developed countries share a strong interest in expanded world oil supplies and lower, or constant, world oil prices. The developed countries and the oil-importing less-developed countries are on the *same* side of this North-South issue, not on opposite sides. The conventional way of viewing North-South issues tends to miss or obscure this point. From the standpoint of energy issues, the prevalence of conflicting interests may be less appropriately aligned along axes labelled "North-South" than along those labelled "South versus South," or "North-plus-NOLDC-South" versus "remainder-of-South."

For example, the 1979 oil import bill of about $31 billion paid by all NOLDCs (based on $18-per-barrel oil prices and current NOLDC imports of 4.7 MB/D) probably constitutes at least as great an impediment to more rapid economic development in the NOLDCs as any other aspect of the current (as distinct from the "new") international economic order. Moreover, these costs will probably be steadily rising over the next decade. By 1990, it is estimated that the oil import bill of the NOLDCs will be between $47 billion and $88 billion (in 1979 dollars) over the central range of our demand forecasts.[2] Thus, the incremental costs to the NOLDCs of their *annual* oil imports will almost surely be much higher than the benefits they might plausibly receive from any of the measures of international economic reform sought by these countries: e.g., the stabilization fund advocated by the United Nations Conference on Trade and Development in its Integrated Program of Commodities; or the amounts of debt-service reduction that would ensue from a rescheduling of LDC foreign indebtedness; or the increases in foreign economic assistance that might be obtained from the developed countries of the North.

Of course, the cogency of this point of view differs with respect to different subgroups among the NOLDCs. The rapidly growing NICs (new industrial countries) have been able to surmount the resource burden of drastically increased oil import costs, but most of the NOLDCs have not. For those countries whose large and growing burden of oil import costs acts as a brake on their economic development, the possibility that OPEC might agree to a concessional oil price for NOLDC buyers may warrant exploration.

There are obvious and serious drawbacks to such a proposal, which are discussed under "Research Implications," below. Moreover, its political feasibility and acceptability are remote, at best. Nonetheless, the idea is attractive because it just might be a means for the NOLDCs to obtain supplementary assistance from the "remainder-of-the-South." The two-tier oil-pricing proposal might also be a concrete means by which the U.S., individually, and the "North," as a group, could collaborate with the "NOLDC South" in advancing NOLDC interests *without* seeming to advance their own.

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[2]The range is based on two assumptions: (1) The ratio between NOLDC oil imports and oil consumption is assumed to be the same in 1990 as in 1976 (i.e., 0.84). (2) The minimum estimate of NOLDC oil consumption (6.1 MB/D, Table 14) is associated with an assumed world oil price of $25 per barrel (in 1979 prices), and the maximum estimate in Table 14 (16.0 MB/D) is associated with an assumed oil price of $18 per barrel. It seems likely that these estimates are conservative, i.e., the actual figures are more likely to be higher than lower.

A keener awareness of this point of view might provide several benefits. It might reduce the tendency in some U.S. policy pronouncements to accept and repeat the conventional formulation of LDC issues in "North versus South" terms. It might also remind the NOLDCs of the important interests they share with OECD countries.

RESEARCH IMPLICATIONS

1.   One of the aims of Rand's research on "Energy Utilization in Less-Developed Countries," of which this study is a part, is to develop and apply relatively simple and inexpensive methods of estimating future oil and energy demand in developing countries. In this study, we have experimented with only two formal variants of an aggregative demand-estimating model. The results bear, although in only a limited way, on a general question relating to modeling efforts in this field: In estimating future demand, what is the relative importance that should be ascribed to (a) refinements and sophistication in model specification, as against more mundane concerns, such as the exogenous assumptions (scenarios) that are adopted, (b) the definition and measurements of variables, (c) the quality and comparability of the data used to measure them, and (d) the inclusion or exclusion of dummy variables?[3]

Our results bear on the answer to this question only in the sense that they take into consideration the relative effects on our minimum and maximum demand forecasts of (a) variations in model specification and (b) the effect of the more "mundane concerns" mentioned above. As noted earlier, in terms of the percentage effects on the minimum and maximum forecasts, the "mundane concerns" strongly dominate.

Of course, our conclusion on this point still leaves ample room for indulging preferences and prejudices in answering the original question. Since the model variations we used were so limited in the first place, advocates of a contrary conclusion may still legitimately contend that we did not adequately test the *potential* effects of more substantial model refinements on the demand forecasts.

2.   In future research, more attention should be focused on the separate country subgroupings—new industrial countries, upper-income, middle-income, and lower-income developing countries—than we have devoted to them. As previously noted, the pattern of price and income elasticities for these subgroupings is similar to that of the all-country grouping, but there appear to be a few interesting differences. Price elasticities of demand, for example, appear to be somewhat *lower* for the upper-income NOLDCs than for the NOLDC group as a whole. (See Appendix C.) However, we have not made separate forecasts of the expected oil demands of these subgroupings. Additional research along this line is worth considering.

We particularly recommend that further attention be given to the energy demand and utilization patterns of the oil-importing NICs—Korea, Taiwan, Brazil, Argentina, Hong Kong, and Singapore—both as a separate country grouping and

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[3]Although country dummy variables are an aspect of model specification, they hardly represent "refinement" and "sophistication."

as individual countries. Among the less-developed countries, these are the ones that are "making it," in terms of sustained and rapid economic growth. Their demand and consumption responses to changes in oil prices and income should be especially interesting and instructive. For example: To what extent have these countries relied on market forces and price changes, or on direct controls and rationing, in allocating scarce energy supplies? To what extent, and through what means, have they shifted production toward less energy-intensive output and technology? To what extent have they been able to pass on to others their increased oil-import costs simply by raising prices of their exports?

Gaps and possible inaccuracies in the data for the NICs (e.g., data on oil prices) have limited the work we have been able to do on these countries, based on the sources available to us. However, direct access to data sources in the countries themselves would alleviate some of these problems. Because NIC experience in relating energy-use patterns and policies to significant economic growth has potential importance for the NOLDCs, further research focusing directly on these new industrial countries is certainly warranted.

3. Studies, including this one, of energy and oil demand typically look at only one side of the relationship between economic development and energy use, namely, the effect of income growth and oil-price increases on energy (oil) demand. Econometric research should also focus on the reverse relationship: the effect of changes in energy use and energy prices on growth. Specifically, what is the relationship between increases in real oil prices, as an independent variable, and economic growth (in the NOLDCs as a group, and for various country subgroups, especially the NICs), as the dependent variable? Do oil price increases of X percent "cause" (contribute to) a decrease of Y percent in the economic growth of the importing countries, after proper allowance has been made for the effects of other variables?

These questions confront the familiar identification problem. Effects run both ways: prices and income growth affect energy use, and prices and energy use affect economic growth. It may be possible to resolve this problem through various modeling efforts that make proper allowance for both types of interaction, as well as for other influences on growth besides energy prices and uses.

The policy relevance of this line of enquiry is indistinct, but worth considering. For example, NICs such as Korea and Taiwan have managed to avoid or limit the growth-inhibiting effect of high energy prices. In principle, then, either the coefficient describing the effect of energy prices on growth has been small for these countries, or it has been offset by other variables with higher coefficients, e.g., output in sectors with major economies of scale, or exports in fields with large comparative cost advantages, etc. It would be useful to identify and calibrate these "other variables" in order to formulate and articulate U.S. policy toward the developing countries in particular and toward North-South relations in general.

4. A final research suggestion relates to our previous comments on a two-tier oil-pricing policy. Initially, and quite independent of that policy, it would be worthwhile to investigate the extent to which the effective prices for oil and oil products actually paid by NOLDCs have been *below* quoted world prices. To what extent have oil exporters provided rebates, or concessional "offset" loans, or "tied" aid or other forms of resource transfers to NOLDCs, thereby lowering the effective oil prices paid by these countries?

Against this background, the possibility of a two-tier oil-pricing policy might be usefully explored. The essential idea would be for oil exporters to charge a lower price for specified amounts of oil exported to and consumed by the NOLDCs (or at least the middle- and lower-income NOLDCs) than is charged on world markets. The aim of the lower price would be to reduce the inhibiting effect of high and rising oil import costs on the development of these countries. For the oil exporters, the principal reason for considering such a pricing policy would be to contribute to the development of their less-fortunate non-OPEC-members of the "South." Although political benefits for OPEC members might be associated with this course of action, these reasons might not be persuasive. Even so, advocacy of such a policy (by the NOLDCs and by the "North") could still have political merit.

Apart from its political acceptability, the idea would face some obvious and serious drawbacks. As in any price-controlled market, incentives would be created for leakages (or "black markets"). Favored NOLDCs might try to boost their imports in order to re-export. Or multinational companies might relocate refining capacity in the favored countries to qualify for preferential oil prices. To avoid these pitfalls, it will be necessary to navigate the murky waters of allocations, quotas, and possible international recriminations.

In the face of such formidable difficulties, why consider the two-tier oil price proposal at all? There are two reasons: (1) primarily because it may be a means of increasing financial assistance from the OPEC-"South" to the NOLDC-"South"; and (2) because it may enable the U.S. and the "North" to take a positive initiative that will further the interests of the NOLDC "South" without either advancing or hindering their own.

Research on this proposal would need to (a) elaborate it in some detail; (b) examine whatever precedents exist that may be a useful source of relevant experience; and (c) consider how a two-tier pricing system might work, how to deal with and set quotas for NOLDC importers, how to resolve or ease the difficulties mentioned above, and how to monitor and implement such a pricing system.

Appendix A

DERIVATION OF THE DEMAND MODEL

Using the same symbols referred to in Chapter 3, derivation of the partial adjustment or lagged adjustment model (1), can be summarized as follows:

1. A desired, or target, level of energy or oil demand, Q_t^* at any time, t, is assumed to depend on the price of energy (oil), and the prevailing level of economic activity or income:

$$Q_t^* = a_0 \, Y_t^\alpha \, P_t^\beta \, ,$$

with   (A.1)

$$\frac{\partial Q^*}{\partial Y} > 0, \quad \frac{\partial Q^*}{\partial P} < 0 \, .$$

2. The *actual* level of demand, Q_t, adjusts to the desired level, Q_t^* by a process that occurs gradually over time. The speed of adjustment depends on the ratio between the actual level and the level prevailing in the previous period t − 1, compared with the corresponding ratio between the desired level and the previously prevailing level:

$$\frac{Q_t}{Q_{t-1}} = \left(\frac{Q_t^*}{Q_{t-1}} \right)^{1-\lambda}$$ (A.2)

The parameter, λ, indicates the speed with which the adjustment takes place: (1 < λ < 0). When λ = 0, actual demand adjusts quickly to desired demand; λ = 1 implies slow and protracted adjustment.

3. Substituting (A.1) into (A.2), results in

$$Q_t = a_0 \left(Y_t^\alpha P_t^\beta \right)^{1-\lambda} Q_{t-1}^\lambda \, ,$$ (A.3)

or model (1) referred to in the text.

Appendix B

SELECTED REGRESSION RESULTS

This appendix presents the regression statistics discussed under "Estimation of Income and Price Elasticities" in Chapter 3. Regression coefficients, t-statistics, and standard deviations for each aggregate model are given in Table B.1, and those for the per capita models are shown in Table B.2. Tables B.3, B.4, and B.5 present the oil demand forecasts for all the income growth and oil price growth scenarios referred to in the text.

Table B.1

REGRESSION STATISTICS FOR AGGREGATE NOLDC OIL AND ENERGY DEMAND

Dummy Variables and Variable Definitions[a]	Regression Coefficients				t-Statistics[b]				Standard Error	R^2
	Q(t-1)	P(t)	Y(t)	Y(t-1)	Q(t)	P(t)	Y(t)	Y(t-1)		
Oil Demand										
[2]	0.976	-0.055	0.029	0.0	127.17	-4.99	3.37	0.0	0.133	0.9940
	0.978	-0.043	0.030	0.0	124.88	-4.17	3.43	0.0	0.134	0.9939
	0.976	-0.049	0.180	-0.153	127.71	-4.39	3.11	-2.66	0.131	0.9941
[2]	0.978	-0.039	0.197	-0.169	125.66	-3.80	3.40	-2.94	0.132	0.9941
[1]	0.458	-0.071	0.117	0.0	12.14	-3.62	3.23	0.0	0.108	0.9960
[1,2]	0.466	-0.049	0.117	0.0	12.28	-3.07	3.19	0.0	0.109	0.9960
[1]	0.462	-0.072	0.180	-0.090	12.19	-3.71	3.36	-1.50	0.108	0.9960
[1,2]	0.470	-0.050	0.178	-0.087	12.31	-3.14	3.28	-1.43	0.109	0.9960
[3]	0.986	-0.059	0.017	0.0	178.49	-5.32	3.10	0.0	0.133	0.9940
[2,3]	0.988	-0.047	0.017	0.0	175.83	-4.52	3.10	0.0	0.134	0.9939
[3]	0.986	-0.059	0.071	-0.055	179.19	-5.37	2.71	-2.14	0.132	0.9941
[2,3]	0.988	-0.047	0.069	-0.052	176.69	-4.64	2.60	-2.01	0.133	0.9940
[1,3]	0.481	-0.076	0.013	0.0	12.91	-3.82	0.85	0.0	0.109	0.9959
[1,2,3]	0.490	-0.054	0.012	0.0	13.08	-3.31	0.78	0.0	0.110	0.9959
[1,3]	0.484	-0.072	0.053	-0.054	13.02	-3.62	2.23	-2.20	0.108	0.9960
[1,2,3]	0.493	-0.050	0.053	-0.056	13.18	-3.11	2.22	-2.25	0.109	0.9960
Total Energy Demand										
	0.974	-0.041	0.030	0.0	133.67	-4.15	3.42	0.0	0.133	0.9948
[2]	0.974	-0.037	0.031	0.0	129.70	-3.80	3.42	0.0	0.135	0.9946
	0.973	-0.037	0.178	-0.148	133.67	-3.74	3.24	-2.72	0.132	0.9948
[2]	0.973	-0.034	0.188	-0.157	129.72	-3.48	3.33	-2.81	0.135	0.9947
[1]	0.564	-0.061	0.131	0.0	17.19	-3.10	3.89	0.0	0.113	0.9962
[1,2]	0.556	-0.060	0.137	0.0	16.56	-3.67	3.86	0.0	0.114	0.9962
[1]	0.554	-0.062	0.144	-0.011	16.77	-3.19	2.76	-0.19	0.112	0.9963
[1,2]	0.544	-0.061	0.131	0.016	16.07	-3.78	2.44	0.27	0.113	0.9963
[3]	0.985	-0.045	0.016	0.0	190.09	-4.47	2.81	0.0	0.133	0.9947
[2,3]	0.986	-0.040	0.016	0.0	185.82	-4.13	2.79	0.0	0.136	0.9946
[3]	0.984	-0.046	0.066	-0.050	189.47	-4.56	2.51	-1.95	0.133	0.9947
[2,3]	0.985	-0.041	0.065	-0.049	185.24	-4.22	2.43	-1.87	0.136	0.9946
[1,3]	0.586	-0.065	0.010	0.0	17.91	-3.23	0.68	0.0	0.114	0.9961
[1,2,3]	0.578	-0.064	0.009	0.0	17.22	-3.85	0.59	0.0	0.115	0.9961
[1,3]	0.575	-0.060	0.056	-0.059	17.74	-3.03	2.30	-2.42	0.013	0.9962
[1,2,3]	0.567	-0.061	0.052	-0.056	17.04	-3.69	2.11	-2.26	0.114	0.9962

NOTE: The letters at top of columns are as defined in the text: Q = oil (energy) demand; P = oil (energy) price); Y = income (GDP); t = year.

[a]The following explanation applies to the numbers shown in this column: [1] signifies that country dummy variables were used in the regression equation whose coefficients appear in the adjacent row to the right; [2] signifies that "own-price" (P''_t) was used to measure oil or energy prices (where [2] does not appear, deflated Ras Tanura prices were used); [3] signifies that income (GDP) was measured by $Y'_{i,t}$ (with the U.S. price deflator employed as discussed in the text; where [3] does not appear, the measure of income used is Y_t with deflation by the local price deflator). Thus, where [2,3] appears at the left, the adjacent regression equation (a) did *not* use country dummies, (b) defined the price variable as P'', and (c) defined the income variable as Y'_t.

The model (2) regression estimates are those in which Y_{t-1} appears; the other coefficients refer to model (1).

Seventy-seven NOLDCs are included in the analysis.

[b]Formal tests of serial correlation, such as the Durbin-Watson test, were not applied to our data. We did not think they were necessary for the models with dummy variables, since such models would correct for any error components that were constant within countries. For the models without dummies, we examined plots of residuals within each country (while looking for outliers), to confirm that there were no apparent trends in the residuals.

Table B.2

REGRESSION STATISTICS FOR PER CAPITA NOLDC OIL AND ENERGY DEMAND

Dummy Variables and Variable Definitions[a]	Regression Coefficients				t-Statistics[b]				Standard Error	R^2
	Q(t-1)	P(t)	Y(t)	Y(t-1)	Q(t)	P(t)	Y(t)	Y(t-1)		
Oil Demand										
	0.966	-0.054	0.055	0.0	108.45	-4.86	3.81	0.0	0.134	0.9903
[2]	0.965	-0.041	0.059	0.0	107.21	-4.07	4.05	0.0	0.136	0.9902
	0.970	-0.047	0.234	-0.192	109.52	-4.19	4.17	-3.30	0.133	0.9906
[2]	0.970	-0.037	0.249	-0.205	108.53	-3.63	4.43	-3.50	0.134	0.9905
[1]	0.431	-0.073	0.144	0.0	11.48	-3.71	4.09	0.0	0.109	0.9937
[1,2]	0.440	-0.050	0.143	0.0	11.65	-3.06	4.01	0.0	0.110	0.9936
[1]	0.439	-0.075	0.226	-0.121	11.57	-3.82	4.40	-2.12	0.108	0.9938
[1,2]	0.449	-0.050	0.226	-0.124	11.74	-3.16	4.35	-2.12	0.109	0.9937
[3]	0.986	-0.059	0.020	0.0	182.43	-5.23	2.86	0.0	0.135	0.9902
[2,3]	0.988	-0.045	0.021	0.0	180.15	-4.36	2.97	0.0	0.137	0.9901
[3]	0.986	-0.059	0.090	-0.071	183.42	-5.31	3.42	-2.75	0.134	0.9904
[2,3]	0.988	-0.046	0.087	-0.067	181.20	-4.49	3.28	-2.57	0.135	0.9903
[1,3]	0.458	-0.081	0.028	0.0	12.30	-4.03	1.79	0.0	0.110	0.9935
[1,2,3]	0.468	-0.056	0.026	0.0	12.50	-3.41	1.67	0.0	0.111	0.9935
[1,3]	0.463	-0.077	0.070	-0.057	12.41	-3.84	2.94	-2.32	0.109	0.9936
[1,2,3]	0.473	-0.053	0.070	-0.059	12.61	-3.23	2.92	-2.40	0.110	0.9936
Total Energy Demand										
	0.965	-0.041	0.056	0.0	115.91	-4.04	4.05	0.0	0.135	0.9908
[2]	0.964	-0.036	0.061	0.0	112.63	-3.73	4.27	0.0	0.137	0.9906
	0.969	-0.036	0.231	-0.188	116.04	-3.54	4.32	-3.39	0.134	0.9909
[2]	0.967	-0.032	0.242	-0.195	112.91	-3.33	4.41	-3.41	0.136	0.9907
[1]	0.541	-0.065	0.146	0.0	16.38	-3.27	4.45	0.0	0.114	0.9934
[1,2]	0.534	-0.061	0.155	0.0	15.79	-3.69	4.47	0.0	0.115	0.9934
[1]	0.536	-0.066	0.201	-0.073	16.03	-3.36	4.00	-1.30	0.113	0.9935
[1,2]	0.527	-0.062	0.196	-0.053	15.38	-3.79	3.78	-0.92	0.114	0.9935
[3]	0.986	-0.045	0.019	0.0	188.32	-4.38	2.65	0.0	0.136	0.9906
[2,3]	0.987	-0.040	0.020	0.0	184.13	-4.04	2.76	0.0	0.139	0.9904
[3]	0.985	-0.045	0.086	-0.069	187.90	-4.46	3.27	-2.65	0.136	0.9907
[2,3]	0.986	-0.041	0.086	-0.067	183.67	-4.11	3.19	-2.53	0.138	0.9905
[1,3]	0.565	-0.071	0.022	0.0	17.11	-3.53	1.44	0.0	0.115	0.9932
[1,2,3]	0.558	-0.067	0.020	0.0	16.47	-3.98	1.33	0.0	0.117	0.9932
[1,3]	0.555	-0.067	0.075	-0.068	16.95	-3.34	3.07	-2.78	0.114	0.9934
[1,2,3]	0.548	-0.063	0.071	-0.065	16.31	-3.81	2.88	-2.63	0.115	0.9934

NOTE: The letters at top of columns are as defined in the text: Q = oil (energy) demand;   P = oil (energy price);   Y = income (GDP);   t = year.

[a]The following explanation applies to the numbers shown in this column: [1] signifies that country dummy variables were used in the regression equation whose coefficients appear in the adjacent row to the right;   [2] signifies that "own-price" (P''_t) was used to measure oil or energy prices (where [2] does not appear, deflated Ras Tanura prices were used);   [3] signifies that income (GDP) was measured by $Y'_{i,t}$ (with the U.S. price deflator employed as discussed in the text; where [3] does not appear, the measure of income used is Y_t with deflation by the local price deflator, instead). Thus, where [2,3] appears at the left, the adjacent regression equation (a) did *not* use country dummies, (b) defined the price variable as P'', and (c) defined the income variable as Y'_t.

The model (2) regression estimates are those in which Y_{t-1} appears; the other coefficients refer to model (1).

[b]Formal tests of serial correlation, such as the Durbin-Watson test, were not applied to our data.   We did not think they were necessary for the models with dummy variables, since such models would correct for any error components that were constant within countries.   For the models without dummies, we examined plots of residuals within each country (while looking for outliers), to confirm that there were no apparent trends in the residuals.

Table B.3

OIL DEMAND FORECASTS TO 1990: ALL COUNTRIES

Country Dummy Variables	Adjustment to Income Change	Dependent Variable Form	Growth Rates (%) GDP	Growth Rates (%) Price	Oil Demand (MB/D) Actual, 1976	Oil Demand (MB/D) Forecast 1980	Forecast 1985	Forecast 1990	Oil Demand Forecast Standard Errors[a] 1980	Std Err 1985	Std Err 1990	Oil Demand (MB/D) Range of Forecasts Due to Definition of Variables 1980	Range 1985	Range 1990
Absent	Delayed; model (1)	Aggregate	3	3	5.60	6.58	7.84	9.09	0.64	1.02	1.40	6.23-6.58	6.86- 7.84	7.28- 9.09
			3	5	5.60	6.49	7.47	8.24	0.63	0.97	1.27	6.10-6.49	6.41- 7.47	6.33- 8.24
			7	3	5.60	6.71	8.37	10.41	0.65	1.09	1.60	6.30-6.71	7.13- 8.37	7.89-10.41
			7	5	5.60	6.61	7.98	9.44	0.64	1.03	1.45	6.17-6.61	6.66- 7.98	6.85- 9.44
		Per capita	3	3	5.60	6.48	7.56	8.59	0.62	0.94	1.23	6.18-6.48	6.73- 7.56	7.06- 8.59
			3	5	5.60	6.39	7.23	7.85	0.61	0.90	1.12	6.06-6.39	6.29- 7.23	6.13- 7.85
			7	3	5.60	6.73	8.57	11.04	0.64	1.06	1.58	6.26-6.73	7.05- 8.57	7.76-11.04
			7	5	5.60	6.64	8.20	10.10	0.63	1.02	1.44	6.14-6.64	6.58- 8.20	6.74-10.10
	Immediate; model (2)	Aggregate	3	3	5.60	6.45	7.51	8.55	0.61	0.94	1.27	6.14-6.45	6.65- 7.51	6.94- 8.55
			3	5	5.60	6.37	7.19	7.83	0.60	0.90	1.16	6.02-6.37	6.21- 7.19	6.03- 7.83
			7	3	5.60	6.73	8.41	10.45	0.64	1.06	1.55	6.26-6.73	7.03- 8.41	7.71-10.45
			7	5	5.60	6.64	8.05	9.56	0.63	1.01	1.42	6.13-6.64	6.56- 8.05	6.70- 9.56
		Per capita	3	3	5.60	6.36	7.29	8.16	0.60	0.89	1.15	6.06-6.36	6.44- 7.29	6.61- 8.16
			3	5	5.60	6.29	7.00	7.53	0.59	0.85	1.06	5.94-6.29	6.02- 7.00	5.73- 7.53
			7	3	5.60	6.74	8.51	10.79	0.63	1.04	1.52	6.20-6.74	6.88- 8.51	7.47-10.79
			7	5	5.60	6.66	8.18	9.95	0.62	0.99	1.40	6.07-6.66	6.43- 8.18	6.48- 9.95
Present[b]	Delayed; model (1)	Aggregate	3	3	5.60	7.12	9.74	13.33	0.30	0.41	0.56	7.12-7.37	9.74-10.63	13.33-15.34
			3	5	5.60	7.08	9.59	13.01	0.30	0.40	0.55	7.08-7.30	9.59-10.37	13.01-14.75
			7	3	5.60	7.35	10.49	14.97	0.31	0.44	0.63	7.19-7.55	10.02-11.16	13.98-16.51
			7	5	5.60	7.30	10.33	14.60	0.31	0.43	0.61	7.13-7.48	9.84-10.92	13.59-15.94
		Per capita	3	3	5.60	7.18	9.91	13.67	0.30	0.41	0.57	7.18-7.46	9.91-10.88	13.67-15.88
			3	5	5.60	7.14	9.76	13.35	0.30	0.40	0.55	7.14-7.38	9.76-10.61	13.35-15.27
			7	3	5.60	7.46	10.80	15.65	0.31	0.45	0.65	7.28-7.67	10.30-11.52	14.57-17.31
			7	5	5.60	7.41	10.64	15.28	0.31	0.44	0.63	7.23-7.60	10.12-11.27	14.17-16.73
	Immediate; model (2)	Aggregate	3	3	5.60	7.17	9.90	13.69	0.30	0.41	0.57	7.12-7.37	9.84-10.57	13.61-15.17
			3	5	5.60	7.12	9.75	13.36	0.30	0.41	0.56	7.07-7.30	9.68-10.33	13.25-14.64
			7	3	5.60	7.36	10.50	15.01	0.31	0.44	0.63	7.13-7.56	9.83-11.20	13.59-16.60
			7	5	5.60	7.31	10.34	14.64	0.30	0.43	0.61	7.08-7.49	9.67-10.95	13.23-16.02
		Per capita	3	3	5.60	7.25	10.15	14.22	0.30	0.42	0.59	7.20-7.46	10.05-10.85	14.05-15.79
			3	5	5.60	7.20	9.99	13.87	0.30	0.41	0.57	7.14-7.39	9.88-10.61	13.68-15.24
			7	3	5.60	7.46	10.82	15.70	0.31	0.45	0.65	7.22-7.68	10.13-11.58	14.20-17.45
			7	5	5.60	7.41	10.65	15.33	0.30	0.44	0.63	7.17-7.60	9.96-11.32	13.83-16.85

NOTE: Projections assume a steady population increase of 2.7 percent per year and percentage rates of GDP growth and price growth as indicated.

[a] Approximate standard errors were chosen so that [forecast] +/- [standard error] nearly equals the interval obtained by exponentiating the logarithmic prediction interval.

[b] A time-trend variable is included in these forecasts.

Table B.4

PERCENTAGE RANGE OF NOLDC OIL DEMAND FORECASTS: RANGE DUE TO FORECAST STANDARD ERRORS

Range of Forecasts and Share of World[a] Demand

Country Dummy Variables	Adjustment to Income Change	Dependent Variable Form	GDP	Price	1980 MB/D	1980 (%) OECD	1980 (%) WAES	1980 (%) Eden	1985 MB/D	1985 (%) OECD	1985 (%) WAES	1985 (%) Eden	1990 MB/D	1990 (%) OECD[b]	1990 (%) WAES	1990 (%) Eden
Absent	Delayed; model (1)	Aggregate	3	3	5.97-7.25	12-15	11-13	13-16	6.89- 8.92	12-16	11-14	13-17	7.80-10.60	0	11-14	14-20
			3	5	5.89-7.14	12-15	11-13	13-15	6.56- 8.50	12-15	10-13	12-16	7.07- 9.61	0	10-13	13-18
			7	3	6.09-7.39	12-15	11-14	13-16	7.36- 9.53	13-17	12-15	14-18	8.93-12.14	0	12-16	17-23
			7	5	6.00-7.29	12-15	11-13	13-16	7.01- 9.08	12-16	11-14	13-17	8.10-11.01	0	11-15	15-20
		Per capita	3	3	5.89-7.13	12-15	11-13	13-15	6.68- 8.56	12-15	11-14	13-16	7.45- 9.90	0	10-13	14-18
			3	5	5.81-7.03	12-14	11-13	12-15	6.39- 8.18	11-14	10-13	12-15	6.81- 9.06	0	9-12	13-17
			7	3	6.12-7.40	12-15	11-14	13-16	7.57- 9.70	13-17	12-15	14-18	9.57-12.73	0	13-17	18-24
			7	5	6.04-7.30	12-15	11-13	13-16	7.24- 9.28	13-16	11-15	14-18	8.76-11.65	0	12-16	16-22
	Immediate; model (2)	Aggregate	3	3	5.87-7.09	12-14	11-13	13-15	6.63- 8.52	12-15	10-13	13-16	7.38- 9.91	0	10-13	14-18
			3	5	5.79-7.00	12-14	11-13	12-15	6.35- 8.15	11-14	10-13	12-15	6.75- 9.07	0	9-12	13-17
			7	3	6.12-7.39	12-15	11-14	13-16	7.42- 9.53	13-17	12-15	14-18	9.02-12.11	0	12-16	17-22
			7	5	6.04-7.30	12-15	11-13	13-16	7.10- 9.13	13-16	11-14	13-17	8.25-11.09	0	11-15	15-21
		Per capita	3	3	5.80-6.99	12-14	11-13	12-15	6.46- 8.23	11-15	10-13	12-16	7.09- 9.39	0	10-13	13-17
			3	5	5.73-6.90	12-14	11-13	12-15	6.20- 7.91	11-14	10-13	12-15	6.54- 8.66	0	9-12	12-16
			7	3	6.14-7.40	12-15	11-14	13-16	7.54- 9.61	13-17	12-15	14-18	9.38-12.41	0	13-17	17-23
			7	5	6.06-7.31	12-15	11-13	13-16	7.24- 9.23	13-16	11-15	14-17	8.65-11.44	0	12-15	16-21
Present	Delayed; model (1)	Aggregate	3	3	6.83-7.43	14-15	13-14	15-16	9.34-10.16	17-18	15-16	18-19	12.78-13.90	0	17-19	24-26
			3	5	6.78-7.38	14-15	13-14	15-16	9.20-10.00	16-18	15-16	17-19	12.47-13.57	0	17-18	23-25
			7	3	7.05-7.67	14-16	13-14	15-16	10.06-10.94	18-19	16-17	19-21	14.35-15.61	0	19-21	27-29
			7	5	7.00-7.62	14-16	13-14	15-16	9.90-10.77	18-19	16-17	19-20	14.00-15.23	0	19-21	26-28
		Per capita	3	3	6.89-7.49	14-15	13-14	15-16	9.51-10.33	17-18	15-16	18-19	13.12-14.25	0	18-19	24-26
			3	5	6.85-7.44	14-15	13-14	15-16	9.36-10.17	17-18	15-16	18-19	12.81-13.92	0	17-19	24-26
			7	3	7.16-7.77	15-16	13-14	15-17	10.36-11.26	18-20	16-18	20-21	15.01-16.31	0	20-22	28-30
			7	5	7.11-7.72	14-16	13-14	15-17	10.21-11.09	18-20	16-18	19-21	14.66-15.93	0	20-21	27-30
	Immediate; model (2)	Aggregate	3	3	6.87-7.47	14-15	13-14	15-16	9.50-10.33	17-18	15-16	18-19	13.13-14.28	0	18-19	24-26
			3	5	6.83-7.42	14-15	13-14	15-16	9.35-10.16	17-18	15-16	18-19	12.81-13.92	0	17-19	24-26
			7	3	7.06-7.67	14-16	13-14	15-16	10.07-10.95	18-19	16-17	19-21	14.39-15.65	0	19-21	27-29
			7	5	7.01-7.62	14-16	13-14	15-16	9.91-10.78	18-19	16-17	19-20	14.04-15.26	0	19-21	26-28
		Per capita	3	3	6.96-7.55	14-15	13-14	15-16	9.74-10.58	17-19	15-17	18-20	13.64-14.81	0	18-20	25-27
			3	5	6.91-7.50	14-15	13-14	15-16	9.59-10.41	17-18	15-16	18-20	13.31-14.46	0	18-19	25-27
			7	3	7.16-7.77	15-16	13-14	15-17	10.38-11.28	18-20	16-18	20-21	15.07-16.36	0	20-22	28-30
			7	5	7.11-7.72	14-16	13-14	15-17	10.22-11.10	18-20	16-18	19-21	14.71-15.97	0	20-22	27-30

NOTE: Projections assume a steady population increase of 2.7 percent per year and percentage rates of GDP growth and price growth as indicated.

[a] Excluding centrally planned economies.

[b] OECD has not made a forecast of NOLDC demand in 1990.

Table B.5

PERCENTAGE RANGE OF NOLDC OIL DEMAND FORECASTS: RANGE DUE TO DEFINITION OF VARIABLES

Range of Forecasts and Share of World[a] Demand

Country Dummy Variables	Adjustment to Income Change	Dependent Variable Form	Growth Rates (%) GDP	Growth Rates (%) Price	1980 MB/D	1980 (%) OECD	1980 (%) WAES	1980 (%) Eden	1985 MB/D	1985 (%) OECD	1985 (%) WAES	1985 (%) Eden	1990 MB/D	1990 (%) OECD[b]	1990 (%) WAES	1990 (%) Eden
Absent	Delayed; model (1)	Aggregate	3	3	6.23-6.58	13-13	11-12	13-14	6.86- 7.84	12-14	11-12	13-15	7.28- 9.09	0	10-12	13-17
			3	5	6.10-6.49	12-13	11-12	13-14	6.41- 7.47	11-13	10-12	12-14	6.33- 8.24	0	9-11	12-15
			7	3	6.30-6.71	13-14	12-12	13-14	7.13- 8.37	13-15	11-13	13-16	7.89-10.41	0	11-14	15-19
			7	5	6.17-6.61	13-13	11-12	13-14	6.66- 7.98	12-14	11-13	13-15	6.85- 9.44	0	9-13	13-18
		Per capita	3	3	6.18-6.48	13-13	11-12	13-14	6.73- 7.56	12-13	11-12	13-14	7.06- 8.59	0	10-12	13-16
			3	5	6.06-6.39	12-13	11-12	13-14	6.29- 7.23	11-13	10-11	12-14	6.13- 7.85	0	8-11	11-15
			7	3	6.26-6.73	13-14	12-12	13-14	7.05- 8.57	12-15	11-14	13-16	7.76-11.04	0	10-15	14-20
			7	5	6.14-6.64	12-14	11-12	13-14	6.58- 8.20	12-15	10-13	12-15	6.74-10.10	0	9-14	12-19
	Immediate; model (2)	Aggregate	3	3	6.14-6.45	13-13	11-12	13-14	6.65- 7.51	12-13	11-12	13-14	6.94- 8.55	0	9-12	13-16
			3	5	6.02-6.37	12-13	11-12	13-14	6.21- 7.19	11-13	10-11	12-14	6.03- 7.83	0	8-11	11-15
			7	3	6.26-6.73	13-14	12-12	13-14	7.03- 8.41	12-15	11-13	13-16	7.71-10.45	0	10-14	14-19
			7	5	6.13-6.64	12-14	11-12	13-14	6.56- 8.05	12-14	10-13	12-15	6.70- 9.56	0	9-13	12-18
		Per capita	3	3	6.06-6.36	12-13	11-12	13-14	6.44- 7.29	11-13	10-12	12-14	6.61- 8.16	0	9-11	12-15
			3	5	5.94-6.29	12-13	11-12	13-13	6.02- 7.00	11-12	10-11	11-13	5.73- 7.53	0	8-10	11-14
			7	3	6.20-6.74	13-14	11-12	13-14	6.88- 8.51	12-15	11-13	13-16	7.47-10.79	0	10-15	14-20
			7	5	6.07-6.66	12-14	11-12	13-14	6.43- 8.18	11-14	10-13	12-15	6.48- 9.95	0	9-13	12-18
Present	Delayed; model (1)	Aggregate	3	3	7.12-7.37	15-15	13-14	15-16	9.74-10.63	17-19	15-17	18-20	13.33-15.34	0	18-21	25-28
			3	5	7.08-7.30	14-15	13-13	15-16	9.59-10.37	17-18	15-16	18-20	13.01-14.75	0	18-20	24-27
			7	3	7.19-7.55	15-15	13-14	15-16	10.02-11.16	18-20	16-18	19-21	13.98-16.51	0	19-22	26-31
			7	5	7.18-7.48	15-15	13-14	15-16	9.84-10.92	17-19	16-17	19-21	13.59-15.94	0	18-21	25-30
		Per capita	3	3	7.18-7.46	15-15	13-14	15-16	9.91-10.88	18-19	16-17	19-21	13.67-15.88	0	18-21	25-29
			3	5	7.14-7.38	15-15	13-14	15-16	9.76-10.61	17-19	15-17	18-20	13.35-15.27	0	18-21	25-28
			7	3	7.28-7.67	15-16	13-14	16-16	10.30-11.52	18-20	16-18	19-22	14.57-17.31	0	20-23	27-32
			7	5	7.23-7.60	15-15	13-14	15-16	10.12-11.27	18-20	16-18	19-21	14.17-16.73	0	19-23	26-31
	Immediate; model (2)	Aggregate	3	3	7.12-7.37	15-15	13-14	15-16	9.84-10.57	17-19	16-17	19-20	13.61-15.17	0	18-20	25-28
			3	5	7.07-7.30	14-15	13-13	15-16	9.68-10.33	17-18	15-16	18-19	13.25-14.64	0	18-20	25-27
			7	3	7.13-7.56	15-15	13-14	15-16	9.83-11.20	17-20	16-18	19-21	13.59-16.60	0	18-22	25-31
			7	5	7.08-7.49	14-15	13-14	15-16	9.67-10.95	17-19	15-17	18-21	13.23-16.02	0	18-22	25-30
		Per capita	3	3	7.20-7.46	15-15	13-14	15-16	10.05-10.85	18-19	16-17	19-20	14.05-15.79	0	19-21	26-29
			3	5	7.14-7.39	15-15	13-14	15-16	9.88-10.61	17-19	16-17	19-20	13.68-15.24	0	18-21	25-28
			7	3	7.22-7.68	15-16	13-14	15-16	10.13-11.58	18-20	16-18	19-22	14.20-17.45	0	19-24	26-32
			7	5	7.17-7.60	15-15	13-14	15-16	9.96-11.32	18-20	16-18	19-21	13.83-16.85	0	19-23	26-31

NOTE: Projections assume a steady population increase of 2.7 percent per year and percentage rates of GDP growth and price growth as indicated.

a Excluding centrally planned economies.

b OECD has not made a forecast of NOLDC demand in 1990.

Appendix C

ESTIMATES OF INCOME AND PRICE
ELASTICITIES OF DEMAND FOR OIL
FOR SUBGROUPS OF NOLDCs

In Tables C.1 and C.2, we show the income and price elasticities of demand for oil; these elasticities were estimated in our regression equations for the subcategories into which we grouped the 77 countries in our sample.

The corresponding elasticities for the all-country regressions are shown in Tables 7 and 8 of the text.

Table C.1

RANGES OF INCOME ELASTICITIES OVER DIMENSIONS OF MODEL VARIATION[a]

Country Dummy Variables	Adjustment to Income Change	Short-Run Income Elasticity		Medium-Run Income Elasticity		Long-Run Income Elasticity		Income Elasticity Realized by 1990[b]	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Oil Demand: High-Income Countries									
Absent	Delayed; model (1)	0.004	0.039	0.069	0.479	0.134	0.919	0.050	0.419
	Immediate; model (2)	0.088	0.171	0.048	0.515	-0.055	0.920	0.078	0.454
Present	Delayed; model (1)	-0.002	0.034	-0.003	0.059	-0.005	0.084	-0.005	0.084
	Immediate; model (2)	0.068	0.132	-0.024	0.036	-0.118	-0.058	-0.117	-0.058
Oil Demand: Middle-Income Countries									
Absent	Delayed; model (1)	0.046	0.065	0.697	0.962	1.348	1.858	0.522	0.733
	Immediate; model (2)	0.280	0.406	0.704	0.792	1.002	1.304	0.598	0.621
Present	Delayed; model (1)	0.011	0.128	0.015	0.176	0.019	0.224	0.019	0.224
	Immediate; model (2)	0.191	0.311	0.044	0.212	-0.103	0.114	-0.103	0.114
Oil Demand: Low-Income Countries									
Absent	Delayed; model (1)	0.043	0.091	0.551	0.972	1.058	1.852	0.467	0.936
	Immediate; model (2)	0.161	0.119	0.582	0.958	1.003	1.716	0.489	0.856
Present	Delayed; model (1)	0.096	0.112	0.120	0.145	0.144	0.178	0.144	0.178
	Immediate; model (2)	0.088	0.122	0.121	0.156	0.129	0.220	0.129	0.220
Oil Demand: New Industrialized Countries									
Absent	Delayed; model (1)	-0.025	0.092	-0.158	0.344	-0.292	0.598	-0.210	0.537
	Immediate; model (2)	0.185	0.503	-0.126	0.483	-0.449	0.469	-0.198	0.474
Present	Delayed; model (1).	0.034	0.055	0.097	0.155	0.159	0.255	0.154	0.247
	Immediate; model (2)	0.361	0.403	0.093	0.142	-0.202	-0.093	-0.150	0.057
Oil Demand: Own-Price Countries									
Absent	Delayed; model (1)	0.037	0.050	0.463	0.651	0.887	1.253	0.401	0.544
	Immediate; model (2)	0.096	0.119	0.501	0.700	0.896	1.281	0.398	0.543
Present	Delayed; model (1)	-0.027	-0.001	-0.038	-0.001	-0.050	-0.001	-0.050	-0.001
	Immediate; model (2)	0.047	0.053	-0.042	-0.003	-0.130	-0.060	-0.130	-0.060

[a]The ranges of variation are due to aggregate versus per capita demand specifications, and to definition of price only. Definition of GDP remains $Y^\dagger$, deflated and then converted to U.S. dollars (see the discussion under "Gross Domestic Product" in Chapter 3).

[b]The predicted percentage change in demand in the year 1990 is given as an income change of 1 percent in 1977, and as constant income thereafter.

Table C.2

RANGES OF PRICE ELASTICITIES OVER DIMENSIONS OF MODEL VARIATION[a]

Country Dummy Variables	Adjustment to Income Change	Short-Run Price Elasticity		Medium-Run Price Elasticity		Long-Run Price Elasticity		Price Elasticity Realized by 1990[b]	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Oil Demand: High-Income Countries									
Absent	Delayed; model (1)	-0.053	-0.034	-0.772	-0.498	-1.494	-0.956	-0.575	-0.379
	Immediate; model (2)	-0.052	-0.031	-0.691	-0.459	-1.339	-0.888	-0.563	-0.345
Present	Delayed; model (1)	-0.091	-0.060	-0.164	-0.116	-0.243	-0.166	-0.243	-0.165
	Immediate; model (2)	-0.089	-0.061	-0.163	-0.121	-0.242	-0.177	-0.241	-0.177
Oil Demand: Middle-Income Countries									
Absent	Delayed; model (1)	-0.031	-0.015	-0.468	-0.220	-0.905	-0.424	-0.351	-0.167
	Immediate; model (2)	-0.030	-0.012	-0.512	-0.210	-0.993	-0.407	-0.350	-0.141
Present	Delayed; model (1)	-0.013	-0.004	-0.018	-0.006	-0.023	-0.007	-0.023	-0.007
	Immediate; model (2)	-0.018	-0.000	-0.025	-0.000	-0.031	-0.000	-0.031	-0.000
Oil Demand: Low-Income Countries									
Absent	Delayed; model (1)	-0.070	-0.060	-0.902	-0.638	-1.733	-1.216	-0.764	-0.615
	Immediate; model (2)	-0.060	-0.055	-0.837	-0.673	-1.613	-1.291	-0.664	-0.590
Present	Delayed; model (1)	-0.116	-0.094	-0.145	-0.122	-0.173	-0.150	-0.173	-0.150
	Immediate; model (2)	-0.121	-0.095	-0.149	-0.122	-0.177	-0.149	-0.177	-0.149
Oil Demand: New Industrialized Countries									
Absent	Delayed; model (1)	-0.030	-0.017	-0.132	-0.099	-0.243	-0.173	-0.177	-0.140
	Immediate; model (2)	-0.019	-0.017	-0.139	-0.083	-0.261	-0.149	-0.166	-0.121
Present	Delayed; model (1)	-0.055	-0.028	-0.156	-0.080	-0.257	-0.131	-0.248	-0.127
	Immediate; model (2)	-0.019	0.001	-0.061	0.004	-0.104	0.007	-0.098	0.006
Oil Demand: Own-Price Countries									
Absent	Delayed; model (1)	-0.057	-0.047	-0.912	-0.543	-1.767	-1.040	-0.652	-0.493
	Immediate; model (2)	-0.053	-0.045	-0.997	-0.607	-1.941	-1.169	-0.626	-0.492
Present	Delayed; model (1)	-0.084	-0.034	-0.115	-0.048	-0.147	-0.061	-0.147	-0.061
	Immediate; model (2)	-0.087	-0.035	-0.120	-0.050	-0.154	-0.065	-0.154	-0.065

[a]The ranges of variation are due to aggregate versus per capita demand specifications, and to definition of price only. Definition of GDP remains Y', deflated and then converted to U.S. dollars (see discussion under "Gross Domestic Product" in Chapter 3).

[b]The predicted percentage change in demand in the year 1990 is given as a price change of 1 percent in 1977, and as constant income thereafter.

Appendix D

RELATIONSHIP BETWEEN THE ADJUSTMENT LAG λ AND THE MEANING OF THE LONG-RUN ELASTICITIES

This appendix extends the discussion of income and price elasticities in Chapter 3, in which we describe the variation in the length of the long-run time span as it relates to the adjustment (Koyck) lag.

For model (1),[1] $\alpha(1 - \lambda)$ and $\beta(1 - \lambda)$ represent the short-run (SR) income and price elasticities, respectively, which are given in Tables 7 and 8 of the text. As indicated in footnote e to Table 7, the realized elasticity for a period of n years is

$$\text{(SR elasticity)} \cdot \left(\frac{1 - \lambda^n}{1 - \lambda} \right),$$

where λ is the adjustment lag and $0 \leq \lambda \leq 1$. Clearly, as n approaches infinity, this realized elasticity becomes the long-run (LR) elasticity:

$$\text{LR elasticity} = \text{SR elasticity} \cdot \left(\frac{1}{1 - \lambda} \right).$$

For relatively low values of λ, however, the realized elasticity and the LR elasticity are, for our purposes, equal to each other for various values of n. This ultimate adjustment is shown in Table D.1 for various values of λ. For example, when $\lambda = 0.6$ and n = [year-1976], 99.9 percent of the total long-run adjustment of demand to price and income changes will take place after 14 years, or to the year 1990. Expressed in other terms,

$$\begin{pmatrix} \text{Realized} \\ \text{elasticity} \\ \text{to 1990} \end{pmatrix} = \text{SR elasticity} \left. \left(\frac{1 - \lambda^{14}}{1 - \lambda} \right) \right|_{\lambda=0.6} = 0.999 \text{ LR elasticity.}$$

We have transformed Table D.1 into a family of curves in Fig. D.1 to illustrate the role played by the adjustment (Koyck) lag λ.

For model (2), we follow what has been said in footnote e to Table 7.

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[1] See Eq. (1) in Chapter 3.

Table D.1

PERCENTAGE OF LONG-TERM ADJUSTMENT OF DEMAND TO INCOME
AND PRICE CHANGES AFTER n YEARS, GIVEN A
SPECIFIED LAG PARAMETER

Adjustment Lag λ	Percent of Ultimate Adjustment				
	1980	1985	1990	2000	2076
0	100	100	100	100	100
.20	99.8	100	100	100	100
.40	97.4	99.0	100	100	100
.60	87.0	98.9	99.9	100	100
.80	59.0	86.6	95.6	99.5	100
.90	34.4	61.3	77.1	92.02	100
.95	18.9	36.9	51.2	70.8	99.4
.96	15.0	30.7	43.5	62.5	98.3
.97	11.5	23.9	34.7	51.9	95.2
.98	7.8	16.6	24.6	38.4	86.7
.99	3.9	8.6	13.1	21.4	63.4

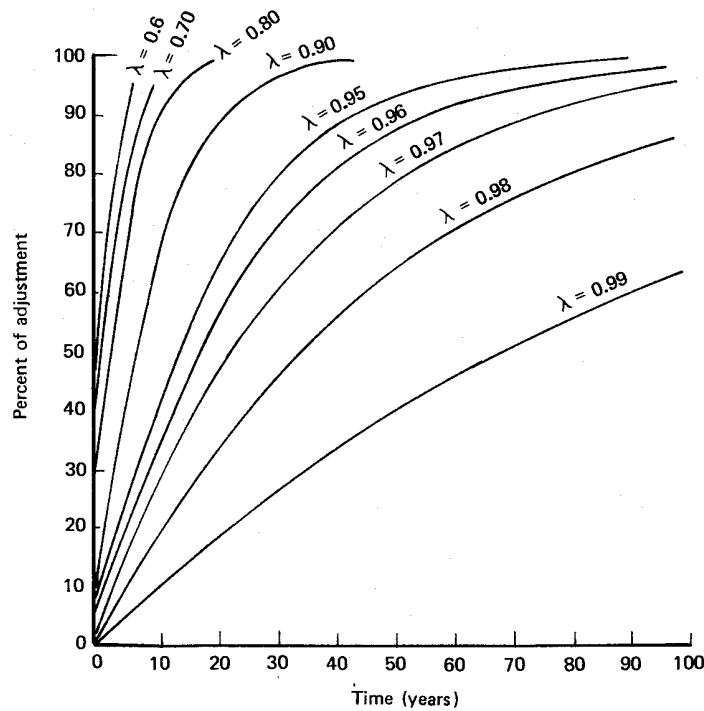NOTE: Entries are $(1 - \lambda^n)/(1 - \lambda)$, where
n = [year-1976].

Fig. D.1—Percentage adjustment of demand to income and
price changes over time, for specified lag parameters